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CSRL-V: Processed ENDF/B-V 227-Neutron-Group and Pointwise Cross-Section Libraries for Criticality Safety, Reactor and Shielding Studies

Prepared by W. E. Ford III, B. R. Diggs, L. M. Petrie, C. C. Webster, R. M. Westfall

Oak Ridge National Laboratory

Prepared for
U.S. Nuclear Regulatory
Commission

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AMPX is a constantly changing cross-section processing system with new modules being added and modifications being made to existing modules as needs dictate. Special appreciation is expressed to N. M. Greene for the updates to the AMPX system needed to process the ENDF/B-V data. In addition, Mr. Greene generated the 1/V and neutron dose-factor data sets included in the CSRL-V fine-group library and wrote the description of the AMPX master library format included herein as Appendix B.

R. Q. Wright modified the UNRESR and UXSR NJOY modules to make the output data compatible with the AMPX TABU module and provided the NPCSL code used to convert the CSRL-V pointwise library from binary to BCD format.

R. W. Roussin and other members of the RSIC staff provided ready access to the ENDF/B-V data and effected the formal ORNL procedure for updating deficient evaluations.

Appreciation is expressed to R. J. Patton for typing the draft and final versions of the report.

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ABSTRACT

A P_3 227-neutron-group cross-section library has been processed for the subsequent generation of problem-dependent fine- or broad-group cross sections for a broad range of applications, including shipping cask calculations, general criticality safety analyses, and reactor core and shielding analyses. The energy group structure covers the range 10^{-5} eV - 20 MeV, including 79 thermal groups below 3 eV. The 129-material library includes processed data for all materials in the ENDF/B-V General Purpose File, several data sets prepared from LENDL data, hydrogen with water- and polyethelene-bound thermal kernels, deuterium with D_2O-bound thermal kernels, carbon with a graphite thermal kernel, a special 1/V data set, and a dose factor data set. The library, which is in AMPX master format, is designated CSRL-V (Criticality Safety Reference Library based on ENDF/B-V data).

Also included in CSRL-V is a pointwise total, fission, elastic scattering, and (n,γ) cross-section library containing data sets for all ENDF/B-V resonance materials. Data in the pointwise library were processed with the infinite dilute approximation at a temperature of 296 K.

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CSRL-V: PROCESSED ENDF/B-V 227-NEUTRON-GROUP AND POINTWISE CROSS-SECTION LIBRARIES FOR CRITICALITY SAFETY, REACTOR, AND SHIELDING STUDIES

I. INTRODUCTION

The U. S. Nuclear Regulatory Commission sponsored the development of a 227-neutron-group cross-section library derived primarily from data in the ENDF/B-V general purpose file.[1] The library,[2] designated CSRL-V (Criticality Safety Reference Library based on ENDF/B-V data), is a data base in AMPX master format[3] for the subsequent generation of problem-dependent fine- and/or broad-group cross sections for a broad range of applications, including shipping cask calculations, general criticality safety analyses, and reactor core and shielding analyses. CSRL-V contains data for approximately 130 materials. The 227-group library and an ENDF/B-V derived pointwise cross-section library prepared in conjunction with the development of the CSRL-V library are available in a single package from the Radiation Shielding Information Center (RSIC) at the Oak Ridge National Laboratory (ORNL).[a]

Problem-dependent cross sections derived from CSRL-V data can be used with the SCALE system[4] and with codes such as KENO-IV,[5] ANISN,[6] XSDRNPM,[7] VENTURE,[8] DOT,[9] and MORSE.[10] CSRL-V data can be coupled with photon-production and photon-interaction multigroup data produced with the AMPX system[3] to produce coupled neutron-gamma cross-section libraries. Modules of the AMPX system offer a full spectrum of cross-section processing capabilities for the CSRL-V data including energy group collapsing, interpolating on Bondarenko factors for self-shielding of unresolved resonance data and temperature corrections, resonance processing with the Nordheim integral method, reformatting, editing, etc. The AMPX system is available from RSIC.[11]

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[a] The United States Department of Energy has determined that ENDF/B-V will, for the present, be limited to users within the United States and AECL (Chalk River), except for the Standards, Dosimetry, Actinide (special purpose), and Fission Product Files, which are available to everyone. This limitation also applies to information roughly equivalent to the ENDF/B-V library such as the CSRL-V multigroup and pointwise libraries. For the present, recipients of CSRL-V will be asked by RSIC to complete and return a form stating that the data will not be transmitted to another installation. Questions concerning this matter should be addressed to RSIC.

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Favorable experiences gained with the generation and utilization of an ENDF/B-IV 218-group master cross-section library for criticality safety studies[12,13] (circa 1976) influenced the processing procedures, the selection of the group structure, and the point-to-multigroup weighting functions used to generate CSRL-V. The ENDF/B-IV 218-group library (the CSRL library) is distributed by RSIC in a code package identified as DLC-43.[14]

Basic sources of nuclear data, specifications, processing system, format, contents, first order data checks, and library implementation hints relating to the CSRL-V master library are described in Section II. Specifications, format, and contents of the CSRL-V pointwise library are presented in Section III. Criteria used in the selection of the CSRL-V group boundaries are given in Appendix A. The format of the CSRL-V master library is given in Appendix B. Definition of reaction type identifiers used in the CSRL-V libraries are given in Appendix C. Finally, a table of contents of the data sets in the CSRL-V master library and the results of a RADE check of data in the library are given on microfiche attached to the inside cover of this report.

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II. CSRL-V 227-NEUTRON-GROUP AMPX MASTER LIBRARY

Multigroup cross-section libraries are characterized by the basic sources of data processed into multigroup format, the processing codes, energy group structure (including the number of groups in the fast, intermediate, and thermal ranges), resonance data (both resolved and unresolved data), weighting function(s), Legendre order of scattering, materials processed, data format, ease of processing the pseudo problem-independent data into problem-dependent data, availability, and validity of the data. Characteristics of the 227-neutron-group CSRL-V AMPX master library are described below.

II.A BASIC SOURCE OF DATA PROCESSED INTO THE CSRL-V MASTER LIBRARY

Basic sources of the evaluated data processed for the library are listed in Table II-1. All available materials in the ENDF/B-V General Purpose File have been processed for the library. In addition, selected materials which are generally needed for criticality safety analysis but which were not available in the ENDF/B-V library were processed from LENDL data.[15,16]

Water-bound and polyethylene-bound hydrogen, D_2O-bound deuterium, and graphite-bound carbon thermal scattering law data of ENDF/B-IV vintage and the appropriate ENDF/B-V epithermal data were used to generate "bound" multigroup CSRL-V data for the specified light nuclides. The thermal scattering data sets are identified in Table II-1. A multigroup dose factor data set was generated for the library from a collection of pointwise data available in the AMPX system. The dose factor data are discussed in Section II.E.6 below.

II.B GENERAL SPECIFICATIONS OF THE CSRL-V MASTER LIBRARY

The fine-group energy structure of the CSRL library has been favorably received as a pseudo-problem-independent structure for the subsequent generation of broad-group cross sections for shipping cask calculations, general criticality safety analyses, etc.[17] Thus, the CSRL structure was slightly modified to give the CSRL-V structure. Specifically, seven groups were added to the CSRL structure in the 6- to 20-MeV range to facilitate the calculation of deep penetration of neutrons in concrete and two groups were added in the 10^{-5} to 10^{-2} eV range to "better treat" neutron capture in gadolinium -- giving a 227-group neutron energy structure. The resulting structure is listed in Table II-2. In addition to the 218-group CSRL structure, the 27-group SCALE[18] and the 16-group Hansen-Roach[19] energy structures are subsets of the CSRL-V structure (see Table II-2).

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Table II-1. The CSRL-V 227-Group AMPX Master Cross-Section Library.

Nuclide	CSRL-V Identifier	ENDF/B-V Data[a] MAT (MOD)	Authors	Lab	Weighting Function[d]	1-d Processes in Data Set[f]	2-d Processes in Data Set[f]	Maximum Order of Scattering	Number of Resolved Resonances Processed	Unresolved Resonance Bondarenko Factor Data[b] Energy Range (eV)	σ_0's	Temperatures (K)	Remarks
1/V	999	N/A	N/A	N/A	B	1,27,1099		0	0				Normalized to unity at 0.0253 eV.
H-1	1001	1301	L. Stewart, R. Lahauve, P. Young	LASL	A	1,2,27,101,102,251-253,1099	2,1007	5[e]	0				MAT 1002 H_2O bound thermal @ 296, 350,400,450,500,600,800, and 1000°K.
H-2	1002	1301	L. Stewart, A. Horsley	LASL	A	1,2,16,27,101,102,251-253,1099	2,16,1007	5[e]	0				MAT 1302 D_2O bound thermal @ 296, 350,400,450,500,600,800, and 1000°K.
H-3	1003	1169	L. Stewart	LASL	A	1,2,16,251,252,253,1099	2,16,1007	3	0				
H-1	1901	1301	L. Stewart, R. Lahauve, P. Young	LASL	A	1,2,27,101,102,251-253,1099	2,1007	5[e]	0				MAT 1011 poly bound thermal @ 296 and 350°K.
He-3	2003	1146	L. Stewart	LASL	A	1,2,27,101,103,104,251-253,1099	2,1007	3	0				
He-4	2004	1270	Risley, Hale, Young	LASL	A	1,2,251-253,1099		3	0				
Li-6	3006	1303	G. Hale, L. Stewart, P. Young	LASL	A	1,2,4,24,27,101-103,105,251-253,1099	2,24,51-91,1007	3	0				
Li-7	3007	1272	R. Lahauve, L. Stewart, M. Battat	LASL	A	1,2,4,16,24,27,101,102,104,251-253,1099	2,16,24,51,91,1007	3	0				
Be-9	4009	1304	Howerton,Perkins	LLL	A	1,2,16,27,101-105,107,251-253,1099	2,6-9,46-49,1007	3	0				
B-10	5010	1305	G. Hale, L. Stewart, P. Young	LASL	A	1,2,4,27,101-104,107,113,251-253,1099	2,51-85,1007	3	0				
B-11	5011	1160	C. Cowan	GE-BWL	A	1,2,4,16,27,101-103,105,107,251-253,1099	2,16,51-53,91,1007	3	0				
C-12	6012	1306	C. Fu, F. Perey	ORNL	A	1,2,4,27,101-104,107,203,204,207,251-253,1099	2,51-68,91,1007	3	0				Free gas thermal data @ 300, 900 and 1200°K.
Graphite	6312	1306	C. Fu, F. Perey	ORNL	A	1,2,4,27,101-104,107,209,210,1099	2,51-68,91,1007,1208	5[e]	0	10^{-5}-1.999x10^7	10^{10}	296,500,800,1200,2000	MAT 1065 Graphite thermal scattering kernel @ 296,500,800,1200, and 2000°K. Bondarenko factor data for MT's 1,2, and 102.
B-14	7014	1275	P. Young, D. Foster, Jr., G. Hale	LASL	A	1,2,4,16,27,101-105,107,108,251-253,1099	2,16,51-82,1007	3	0				
B-15	7015	1307	E. Author, P. Young, G. Hale	LASL	A	1,2,4,16,22,27,28,101-105,107,251-253,1099	2,16,22,28,51-57,91,1007	3	0				
O-16	8016	1276	P. Young, D. Foster, Jr., G. Hale	LASL	A	1,2,4,27,101-104,107,251-253,1099	2,51-89,1007	3	0				
O-17	8017	1317	R. Maguruo	BNL	A	1,2,4,16,27,27,28,101-104,107,251-253,1099	2,16,22,28,51-62,91,1007	3	0				
F-19	9019	1309	C. Fu, D. Larson, F. Perey	ORNL	A	1,2,4,16,22,27,28,101-105,107,251-253,1099	2,16,22,28,51-72,91,1007	3	0				
Na-23	11023	1311	D. Larson	ORNL	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-68,91,1007	3	4				
Mg	12000	1312	D. Larson	ORNL	A	1,2,4,16,22,27,28,101-103,107,251-253,1099	2,16,22,28,51-62,1007	3	0				
Al-27	13027	1313	P. Young, D. Foster, Jr.	LASL	A	1,2,4,16,27,101-105,107,251-253,1099	2,16,51-90,1007	3	0				
Si	14000	1314	Larson, Perey, Drake, Young	ORNL	A	1,2,4,16,22,27,28,101-104,107,251-253,1099	2,16,22,28,51-72,91,1007	3	0				
P-31	15031	1315	R. Howerton	LLL	A	1,2,4,16,27,28,101-103,107,251-253,1099	2,16,28,91,1007	3	0				
S-32	16032	1316	R. Howerton	LLL	A	1,2,4,16,27,28,101-103,105,107,251-253,1099	2,16,28,91,1007	3	0				
Cl	17000	1149	M. Allen, M. Drake	GGA	A	1,2,4,16,22,27,28,101-103,107,251-253,1099	2,16,22,28,51-63,91,1007	3	0				
Ar	18000	7132[c]	R. Howerton	LLL	A	1,2,4,16,27,101-103,107,1099	2,16,91,1007	3	0				
K	19000	1150	M. Drake	GGA	A	1,2,4,16,22,27,28,101-105,107,251-253,1099	2,16,22,28,51-67,91,1007	3	0				
Ca	20000	1320	C. Fu, F. Perey	ORNL	A	1,2,4,16,22,27,28,101-108,111,112,251-253,1099	2,16,22,28,51-73,91,1007	3	0				
Sc-45	21045	7127[c]	R. Howerton	LLL	A	1,27,101,102,1099		0	0				
Ti	22000	1322	C. Philis, A. Smith, R. Howerton	BUR	A	1,2,4,16,17,22,27,28,101-107,111,112,203,207,251-253,1099	2,16,17,22,28,51-62,91,1007	3	0				
V	23000	1323	A. Smith, R. Howerton, F. Mann	ANL	B	1,2,4,16,22,27,28,101-105,107,203,207,251-253,1099	2,16,22,28,51-57,91,1007	3	0				
Cr	24000	1324	A. Prince, T. Burrows	BNL	B	1,2,4,16,17,22,27,28,101-107,203-207,251-253,1022,1099	2,16,17,22,28,51-91,1007	3	86				
Mn-55	25055	1325	S. Mughabghab	BNL	B	1,2,4,16,17,22,27,28,101-104,106,107,251-253,1023,1099	2,16,17,22,28,51-62,91,1007	3	45				
Fe	26000	1326	C. Fu, F. Perey	ORNL	B	1,2,4,16,22,27,28,101-107,251-253,1021,1023,1099	2,16,22,28,51-76,91,1007	3	62				
Co-59	27059	1327	S. Mughabghab	BNL	B	1,2,4,16,22,27,28,101-107,251-253,1021,1023,1099	2,16,22,28,51-61,91,1007	3	74				
Ni	28000	1328	M. Divadeenam	BNL	B	1,2,4,16,22,27,28,101-104,107,111,203,204,207,251-253,1021,1023,1099	2,16,22,28,51-76,91,1007	3	134				
Cu	29000	1329	Fu, Drake, Pricke	ORNL, SAI	B	1,2,4,16,17,22,27,28,101-104,106,107,251-253,1021,1023,1099	2,16,17,22,28,51-61,91,1007	3	49				
Zn-64	30064	7139[c]	R. Howerton	LLL	A	1,27,101,103,1099		0	0				
Ga	31000	7140[c]	R. Howerton, P. Young	LLL, LASL	B	1,2,4,16,27,101-103,107,109	2,16,91,1007	3	0				
Kr-78	36078	1330	A. Prince	BNL	B	1,2,4,16,27,101-107,251-253,1021,1023,1099	2,16,51-53,91,1007	3	5				
Kr-80	36080	1331	A. Prince	BNL	B	1,2,4,16,27,101-107,251-253,1021,1023,1099	2,16,51-56,91,1007	3	6				
Kr-82	36082	1332	A. Prince	BNL	B	1,2,4,16,27,101-107,251-253,1021,1023,1099	2,16,51-59,91,1007	3	3				
Kr-83	36083	1333	A. Prince	BNL	B	1,2,4,16,17,27,101-107,251-253,1021,1023,1099	2,16,17,51-56,91,1007	3	4				
Kr-84	36084	1334	A. Prince	BNL	B	1,2,4,16,27,101-107,251-253,1021,1023,1099	2,16,51-63,91,1007	3	5				
Kr-86	36086	1336	A. Prince	BNL	B	1,2,4,16,17,27,101-105,251-253,1021,1023,1099	2,16,17,51-64,91,1007	3	3				
Zr	40000	1340	M. Drake, D. Sargio, T. Maung	SAI	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-69,91,1007	3	85				
Zr-90	40090	1340	M. Drake, D. Sargio, T. Maung	SAI	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-55,91,1007	3	17				
Zr-91	40091	1386	M. Drake, D. Sargio, T. Maung	SAI	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-61,91,1007	3	15				
Zr-92	40092	1387	M. Drake, D. Sargio, T. Maung	SAI	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-56,91,1007	3	17				
Zr-94	40094	1388	M. Drake, D. Sargio, T. Maung	SAI	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-58,91,1007	3	25				
Zr-96	40096	1389	M. Drake, D. Sargio, T. Maung	SAI	B	1,2,4,16,27,101,102,107,251-253,1021,1023,1099	2,16,51-54,91,1077	3	15				
ZIRO-2	40302				B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-69,91,1007	3	85				Prepared from 999 and 40000.
Nb-93	41093	1189	R. Howerton, A. Smith	LLL, ANL	B	1,2,4,16,17,22,27,101-103,107,251-253,1021,1023,1099	2,16,17,22,51-62,91,1007	3	97	$7.300x10^3$-10^5	$1,10,50,10^2,10^3,10^4,10^5,10^{10}$	300,600,900,1200,2100	
Mo	42000	1321	Howerton, Schmittroth, Schenter	LLL, HEDL	B	1,2,4,16,17,27,101,102,251-253,1021,1023,1099	2,16,17,91,1007	3	33	10^3-10^5	$50,10^2,10^3,10^4,10^{10}$	300,600,900,1200,2100	
Tc-99	43099	1308	Schenter, Livolsi, Schmittroth	HEDL, BAW	B	1,2,4,16,27,101,102,251-253,1021,1023,1099	2,16,51-61,91,1007	3	44	$8.000x10^2$-$1.414x10^5$	$1,10,50,10^2,10^3,10^4,10^{10}$	300,600,900,1200,2100	
Rh-103	45103	1310	Schenter, Livolsi, Schmittroth	HEDL, BAW	B	1,2,4,16,27,101,102,251-253,1021,1023,1099	2,16,51-64,91,1007	3	61				
Ag-107	47107	1371	Schenter, Bhat, Prince, Johnson	HEDL, BNL	B	1,2,4,16,27,101-105,107,251-253,1021,1023,1099	2,16,51-56,91,1007	3	61				
Ag-109	47109	1373	Schenter,Bhat,Prince,Johnson	HEDL, BNL	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-55,91,1007	3	65				
Cd	48000	1281	S. Pearlstein	BNL	A	1,2,4,16,27,107,251-253,1099	2,16,51-54,91,1007	3	0				
Cd-113	48113	1318	Pearlstein, Mann, Schenter	BNL, HEDL	B	1,2,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-53,91,1007	3	14				
Sn	50000	7150[c]	R. Howerton	LLL	B	1,2,4,16,17,27,101102,1099	2,16,17,91,1007	3	0				

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Table II-1. (cont'd)

Nuclide	ENDL-V Identifier	MAT (MOD)	ENDF/B-V Data[a] Authors	Lab	Weighting Function[d]	1-d Processes in Data Set[f]	2-d Processes in Data Set[f]	Maximum Order of Scattering	Number of Resolved Resonances Processed	Unresolved Resonance Bondarenko Factor Data[b] Energy Range (eV)	σ_0's	Temperatures (K)	Remarks
Xe-124	54124	1335	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-102,251-253,1021,1023,1099	2,16,17,51-54,91,1007	3	5				
Xe-126	54126	1339	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-107,251-253,1021,1023,1099	2,16,17,51-54,91,1007	3	5				
Xe-128	54128	1348	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-107,251-253,1021,1023,1099	2,16,17,51-53,91,1007	3	11				
Xe-129	54129	1349	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27 101-105,107,251-253,1021,1023,1099	2,16,17,51-56,91,1007	3	71				
Xe-130	54130	1350	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-105,107,251-253,1021,1023,1099	2,16,17,51-56,91,1007	3	13				
Xe-131	54131	1351	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-105,107,251-253,1021,1023,1099	2,16,17,51-56,91,1007	3	41				
Xe-132	54132	1352	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-105,107,251-253,1021,1023,1099	2,16,17,51-54,91,1007	3	5				
Xe-134	54134	1354	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-105,107,251-253,1021,1023,1099	2,16,17,51-53,91,1007	3	4				
Xe-135	54135	1294	B. Leonard, Jr., K. Stewart	BNW	B	1,2,4,27,101,102,251-253,1099	2,51,91,1007	3	0				
Xe-136	54136	1356	M. Bhat, S. Mughabghab	BNL	B	1,2,4,16,17,27,101-105,107,251-253,1099	2,16,17,51-53,91,1007	3	0				
Cs-133	55133	1355	Schenter, Bhat, Prince, Johnson	BEDL, BNL	B	1,7,4,16,27,101-103,107,251-253,1021,1023,1099	2,16,51-55,91,1007	3	125				
Ba-138	56138	1353	B. Howerton	LLL	B	1,2,4,16,17,27,101-103,107,251-253,1099	2,16,17,91,1007	3	0				
Sm-149	62149	1319	Schenter, Leonard, Stewart	BEDL, BNW	B	1,2,4,16,17,27,101-103,107,251-253,1021,1023, 1099	2,16,17,51-60,91,1007	3	31				
Eu-151	63151	1357	S. Mughabghab	BNL	B	1,2,4,16,17,22,27,28,101-107,251-253,1021, 1023,1099	2,16,17,22,28,51-59,91,1007	3	93	9.881×10^{1}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Eu-152	63152	1292	N. Takahashi	BNL	B	1,2,4,16,17,22,27,28,101-107,251-253,1021, 1023,1099	2,16,17,22,28,51-55,91,1007	3	94	6.130×10^{1}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Eu-153	63153	1359	S. Mughabghab	BNL	B	1,2,4,16,17,22,27,28,101-107,251-253,1021, 1023,1099	2,16,17,22,28,51-61,91,1007	3	73	9.722×10^{1}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Eu-154	63154	1293	N. Takahashi	BNL	B	1,2,4,16,17,22,27,28,101-107,251-253,1021, 1023,1099	2,16,17,22,28,51-55,91,1007	3	73	6.000×10^{1}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Gd-152	64152	1362	B. Maguroo	BNL	B	1,2,4,16,22,27,28,101-103,107,251-253,1021, 1023,1099	2,16,22,28,51-64,91,1007	3	19				
Gd-154	64154	1364	B. Maguroo	BNL	B	1,2,4,16,22,27,28,101-103,107,251-253,1021, 1023,1099	2,16,22,28,51-64,91,1007	3	38				
Gd-155	64155	1365	B. Maguroo	BNL	B	1,2,4,16,22,27,28,101-103,107,251-253,1021, 1023,1099	2,16,22,28,51-64,91,1007	3	94	1.834×10^{2}-1.839×10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Gd-156	64156	1366	B. Maguroo	BNL	B	1,2,4,16,22,27,28,51-64,91,101-103,107,251-253,1007,1021,1023,1099	2,16,27,28,51-64,91,1007	3	32				
Gd-157	64157	1367	B. Maguroo	BNL	B	1,2,4,16,22,27,28,101-103,107,251-253,1021, 1023,1099	2,16,22,28,51-64,91,1007	3	38	3.065×10^{2}-1.839×10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Gd-158	64158	1368	B. Maguroo	BNL	B	1,2,4,16,22,27,28,101-103,107,251-253,1021, 1023,1099	2,16,22,28,51-64,91,1007	3	95				
Gd-160	64160	1370	B. Maguroo	BNL	B	1,2,4,16,22,27,28,101-103,107,251-253,1021, 1023,1099	2,16,22,28,51-58,91,1007	3	46				
Dy-164	66164	1031	B. Leonard, Jr., K. Stewart	BNW	B	1,2,4,16,17,27,101-103,107,251-253,1021, 1023,1099	2,16,17,51-62,91,1007	3	3	2.726×10^{2}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Lu-175	71175	1032	B. Leonard, Jr., K. Stewart	BNW	B	1,2,4,16,17,27,101-103,107,251-253,1021, 1023,1099	2,16,17,51-58,91,1007	3	18	6.800×10^{1}-10^{4}	10^{2},10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Lu-176	71176	1033	B. Leonard, Jr., K. Stewart	BNW	B	1,2,4,16,17,27,101-103,107,251-253,1021, 1023,1099	2,16,22,28,51-58,91,1007	3	23	4.800×10^{1}-10^{4}	$1,10,30,10^{2},10^{3}$, $10^{4},10^{10}$	300,600,900, 1200,2100	
Hf	72000	1372	M. Drake, D. Sargeo, T. Hoang	SAI	B	1,2,4,16,27,101-103,251-253,1021,1023,1099	2,16,51-62,91,1007	3	242	1.200×10^{0}-10^{3}	$1,10,30,10^{2},10^{3}$, $10^{4},10^{10}$	300,600,900, 1200,2100	
Hf-174	72174	1374	M. Drake, D. Sargeo, T. Hoang	SAI	B	1,2,4,16,27,101-103,251-253,1021,1023,1099	2,16,51-53,91,1007	3	12	2.300×10^{2}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Hf-176	72176	1376	M. Drake, D. Sargeo, T. Hoang	SAI	B	1,2,4,16,27,101-103,251-253,1021,1023,1099	2,16,51-53,91,1007	3	24	1.880×10^{1}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Hf-177	72177	1377	M. Drake, D. Sargeo, T. Hoang	SAI	B	1,2,4,16,27,101-103,251-253,1021,1023,1099	2,16,51-60,91,1007	3	101	3.800×10^{2}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Hf-178	72178	1378	M. Drake, D. Sargeo, T. Hoang	SAI	B	1,2,4,16,27,101-103,251-253,1021,1023,1099	2,16,51-53,91,1007	3	27	2.100×10^{1}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Hf-179	72179	1383	M. Drake, D. Sargeo, T. Hoang	SAI	B	1,2,4,16,27,101-103,251-253,1021,1023,1099	2,16,51-54,91,1007	3	31	4.300×10^{2}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Hf-180	72180	1384	M. Drake, D. Sargeo, T. Hoang	SAI	B	1,2,4,16,27,101-103,251-253,1021,1023,1099	2,16,51-53,91,1007	3	22	1.290×10^{0}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Ta-181	73181	1285	Howerton, Perkins, MacGregor	LLL	B	1,2,4,16,17,27,101-103,251-253,1021,1023,1099	2,16,17,51-60,91,1007	3	77	3.360×10^{2}-5.000×10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Ta-182	73182	1127	J. Otter, C. Dunford, K. Ottewitte	AI	B	1,2,4,16,17,27,101,102,251-253,1021,1023,1099	2,16,17,51-58,91,1007	3	11	3.500×10^{1}-10^{4}	$1,10,30,10^{2},10^{3}$, $10^{4},10^{10}$	300,600,900, 1200,2100	
W-182	74182	1128	Otter, Ottewitte, Rose, Young	AI, LASL	B	1,2,4,16,17,27,28,101-103,107,251-253,1021, 1023,1099	2,16,17,28,51-58,91,1007	3	70	4.500×10^{3}-10^{5}	$1,10,30,10^{2},10^{3}$, $10^{4},10^{10}$	300,600,900, 1200,2100	
W-183	74183	1129	Otter, Ottewitte, Rose, Young	AI, LASL	B	1,2,4,16,17,27,28,101-103,107,251-253,1021, 1023,1099	2,16,17,28,51-59,91,1007	3	51	7.650×10^{2}-4.500×10^{4}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
W-184	74184	1130	Otter, Ottewitte, Rose, Young	AI, LASL	B	1,2,4,16,17,27,28,101-103,107,251-253,1021, 1023,1099	2,16,17,28,51-59,91,1007	3	39	2.650×10^{3}-10^{5}	$1,10,30,10^{2},10^{3}$, $10^{4},10^{10}$	300,600,900, 1200,2100	
W-186	74186	1131	Otter, Ottewitte, Rose, Young	AI, LASL	B	1,2,4,16,17,27,28,101-103,107,251-253,1021, 1023,1099	2,16,17,28,51-59,91,1007	3	42	3.200×10^{3}-10^{5}	$1,10,30,10^{2},10^{3}$, $10^{4},10^{10}$	300,600,900, 1200,2100	
Re-185	75185	1083	W. Henderson, J. Zwick	GE	B	1,2,4,16,17,27,28,101,102,251-253,1021, 1023,1099	2,16,17,28,51-58,91,1007	3	31	9.980×10^{1}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Re-187	75187	1084	W. Henderson, J. Zwick	GE	B	1,2,4,16,17,27,28,101,102,251-253,1021, 1023,1099	2,16,17,28,51-61,91,1007	3	25	9.380×10^{1}-10^{3}	$10^{2},10^{3},10^{4},10^{10}$	300,600,900, 1200,2100	
Ir-191	77191	7160[c]	B. Howerton	LLL	B	1,27,101,102,1099		0	0				
Ir-193	77193	7161[c]	B. Howerton	LLL	B	1,27,101,102,1099		0	0				
Au-197	79197	1379	S. Mughabghab	BNL	B	1,2,4,16,17,27,101-103,107,251-253,1099	2,16,17,51-64,91,1007	3	0				
Pb	82000	1382	C. Fu, F. Perey	ORNL	A	1,2,4,16,17,27,101,102,251-253,1099	2,16,17,51-65,91,1007	3	0				
Th-232	90232	1390	Bhat, Smith, Leonard, De Saussure	BNL, ORNL	C	1,2,4,16-18,27,101,102,251-253,451,1018, 1021-1023,1099	2,16,17,51-65,91,1007	3	240	4.800×10^{1}-5.000×10^{3}	$1,10,30,10^{2},10^{3}$, $10^{4},10^{10}$	300,600,900, 1200,2100	

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Table II-1. (Cont'd)

Nuclide	CSEWG-V Identifier	ENDF/B-V Data[a] MAT (MOD)	Authors	Lab	Weighting Function[d]	1-d Processes in Data Set[f]	2-d Processes in Data Set[f]	Maximum Order of Scattering	Number of Resolved Resonances Processed	Unresolved Resonance Bondarenko Factor Data[b] Energy Range (eV)	σ_0's	Temperatures (K)	Remarks
Pa-233	91233	1391	Mann, Schenter, Reich	HEDL, INEL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021,1023,1099	2,16,17,51-55,91,1007	3	35	3.850×10^{3}-10^{5}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
U-233	92233	1393	Stewart, Weston, Mann, et.al.	LASL, ORNL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1099	2,16,17,51-54,91,1007	3	0	6.000×10^{3}-10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
U-234	92234	1394	Divadeenam, Mann, Drake, Reich	BNL, HEDL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-56,91,1007	3	120	1.500×10^{3}-10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
U-235	92235	1395	M. Bhat	BNL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-66,91,1007	3	131	8.200×10^{1}- 2.580×10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
U-236	92236	1396	Divadeenam, Mann, McCrosson, Reich	BNL, HEDL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-56,91,1007	3	182	4.110×10^{3}-10^{5}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
U-238	92238	1398	F. Pennington, A. Smith, W. Poenitz	ANL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-77,91,1007	3	165	4.000×10^{3}- 1.490×10^{5}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Np-237	93237	1337	Mann, Benjamin, Smith, Stein, Reich	HEDL, SRL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-61,91,1007	3	170	1.300×10^{2}- 4.800×10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Pu-238	94238	1338	Mann, Schenter, Atter, Dunford	HEDL, AI	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-65,91,1007	3	16	2.000×10^{3}-10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Pu-239	94239	1399	K. Kujawski, L. Stewart	GE, LASL	C	1,2,4,16-18,27,37,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-76,91,1007	3	129	3.810×10^{3}- 2.500×10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Pu-240	94240	1380	L. Weston	ORNL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-62,91,1007	3	202	3.910×10^{1}- 4.000×10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Pu-241	94241	1381	L. Weston, R. Wright, R. Howerton	ORNL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1099	2,16,17,51-65,91,1007	3	0	1.000×10^{2}- 4.020×10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Pu-242	94242	1347	Mann, Benjamin, Madland, Howerton	HEDL, SRL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-69,91,1007	3	69	9.860×10^{2}-10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Am-241	95241	1361	Mann, Schenter, Weston	HEDL, ORNL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-68,91,1007	3	67	5.800×10^{1}-10^{4}	$1,10,50,10^{2}$, 10^{3},10^{4},10^{10}	300,600,900, 1200,2100	
Am-242m	95401	1369	Mann, Benjamin, Howerton, et.al.	HEDL, SRL, LLL	C	1,2,4,16-18,27,37,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-63,91,1007	3	8	$3.550 - 10^{4}$	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Am-243	95243	1363	Mann, Benjamin, Howerton, et.al.	HEDL, SRL, LLL	C	1,2,4,16-18,27,37,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-67,91,1007	3	221	2.500×10^{2}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Cm-243	96243	1343	Mann, Benjamin, Howerton, et.al.	HEDL, SRL, LLL	C	1,2,4,16-18,27,37,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-65,91,1007	3	17	2.700×10^{1}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Cm-244	96244	1344	Mann, Benjamin, Howerton, et.al.	HEDL, SRL, LLL	C	1,2,4,16-18,27,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-53,91,1007	3	39	3.250×10^{2}-10^{4}	10^{2},10^{3},10^{4}, 10^{10}	300,600,900, 1200,2100	
Cm-245	96245	1345	Benjamin, Howerton	SRL, LLL	C	1,2,4,16-18,27,37,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,91,1007	3	3				
Cm-246	96246	1346	Kinsey-assembler	ANL, SRL, LLL	C	1,2,4,16-18,27,37,101,102,251-253,452,1018, 1021-1023,1099	2,16,17,51-61,91,1007	3	12	3.850×10^{3}-10^{4}	10^{2},10^{3}, 10^{4}, 10^{10}	300,600,900 1200,2100	
Dose Factors	500000	N/A			3	9001-9038,1099							

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Footnotes for Table II-1

a. All neutron data from ENDF/B-V unless otherwise noted.

b. Unless otherwise noted, Bonderenko factors are available for MT's 1, 2, 4, 18 (for fissionable nuclei), 102, and 1000.

c. An evaluation from the LENDL library, not an ENDF/B-V evaluation.

d. The following code is used to identify the weighting functions:

Code	Weight Function
A	10^{-5}-0.1265 eV Maxwellian; 0.1265 eV-1.4 Mev 1/E; 1.4-20 MeV fission.
B	10^{-5}-0.1265 eV Maxwellian; 0.1265 eV-0.75 MeV 1/E; 0.75-20 MeV fission.
C	10^{-5}-0.1265 eV Maxwellian; 0.1265 eV-0.1 MeV 1/E; 0.1-20 MeV fission.

e. Order of scattering in the fast range is P_5; in the thermal range, it's P_3.

f. See Appendix C for the definitions of the process identifiers (MT numbers).

Table II-2. CSRL-V 227-Group Neutron Energy Structure

CSRL-V Group	CSRL Group	27-Group SCALE	16-Group Hansen-Roach	Upper Energy (eV)	Lethargy Range
1	1	1		2.0000+7[a]	(-0.693)-(-0.550)
2				1.7333+7	(-0.550)-(-0.450)
3				1.5683+7	(-0.450)-(-0.375)
4				1.4550+7	(-0.375)-(-0.325)
5				1.3840+7	(-0.325)-(-0.250)
6				1.2840+7	(-0.250)- 0.0
7			1	1.0000+7	0.0 - 0.200
8				8.1873+6	0.200 - 0.441
9	2	2		6.4340+6	0.441 - 0.734
10	3			4.8000+6	0.734 - 0.843
11	4			4.3040+6	0.843 - 1.204
12	5	3	2	3.0000+6	1.204 - 1.395
13	6			2.4790+6	1.395 - 1.446
14	7			2.3540+6	1.446 - 1.687
15	8	4		1.8500+6	1.687 - 1.897
16	9			1.5000+6	1.897 - 1.966
17	10	5	3	1.4000+6	1.966 - 1.998
18	11			1.3560+6	1.998 - 2.027
19	12			1.3170+6	2.027 - 2.079
20	13			1.2500+6	2.079 - 2.120
21	14			1.2000+6	2.120 - 2.207
22	15			1.1000+6	2.207 - 2.293
23	16			1.0100+6	2.293 - 2.386
24	17			9.2000+5	2.386 - 2.408
25	18	6	4	9.0000+5	2.408 - 2.436
26	19			8.7500+5	2.436 - 2.452
27	20			8.6110+5	2.452 - 2.501
28	21			8.2000+5	2.501 - 2.590
29	22			7.5000+5	2.590 - 2.690
30	23			6.7900+5	2.690 - 2.703
31	24			6.7000+5	2.703 - 2.813
32	25			6.0000+5	2.813 - 2.859
33	26			5.7300+5	2.859 - 2.900
34	27			5.5000+5	2.900 - 2.997
35	28			4.9952+5	2.997 - 3.058
36	29			4.7000+5	3.058 - 3.124
37	30			4.4000+5	3.124 - 3.170
38	31			4.2000+5	3.170 - 3.219
39	32	7	5	4.0000+5	3.219 - 3.411
40	33			3.3000+5	3.411 - 3.612
41	34			2.7000+5	3.612 - 3.912
42	35			2.0000+5	3.912 - 4.200
43	36			1.5000+5	4.200 - 4.356

Table II-2. (cont.)

CSRL-V Group	CSRL Group	27-Group SCALE	16-Group Hansen-Roach	Upper Energy (eV)	Lethargy Range
44	37			1.2830+5	4.356 - 4.605
45	38	8	6	1.0000+5	4.605 - 4.768
46	39			8.5000+4	4.768 - 4.804
47	40			8.2000+4	4.804 - 4.893
48	41			7.5000+4	4.893 - 4.920
49	42			7.3000+4	4.920 - 5.116
50	43			6.0000+4	5.116 - 5.259
51	44			5.2000+4	5.259 - 5.298
52	45			5.0000+4	5.298 - 5.404
53	46			4.5000+4	5.404 - 5.809
54	47			3.0000+4	5.809 - 5.991
55	48			2.5000+4	5.991 - 6.377
56	49	9	7	1.7000+4	6.377 - 6.645
57	50			1.3000+4	6.645 - 6.959
58	51			9.5000+3	6.959 - 7.127
59	52			8.0300+3	7.127 - 7.419
60	53			6.0000+3	7.419 - 7.849
61	54			3.9000+3	7.849 - 7.891
62	55			3.7400+3	7.891 - 8.112
63	56	10	8	3.0000+3	8.112 - 8.263
64	57			2.5800+3	8.263 - 8.382
65	58			2.2900+3	8.382 - 8.422
66	59			2.2000+3	8.422 - 8.623
67	60			1.8000+3	8.623 - 8.772
68	61			1.5500+3	8.772 - 8.805
69	62			1.5000+3	8.805 - 9.071
70	63			1.1500+3	9.071 - 9.262
71	64			9.5000+2	9.262 - 9.592
72	65			6.8300+2	9.592 - 9.611
73	66			6.7000+2	9.611 - 9.808
74	67	11	9	5.5000+2	9.808 -10.398
75	68			3.0500+2	10.398 -10.466
76	69			2.8500+2	10.466 -10.637
77	70			2.4000+2	10.637 -10.771
78	71			2.1000+2	10.771 -10.783
79	72			2.0750+2	10.783 -10.858
80	73			1.9250+2	10.858 -10.892
81	74			1.8600+2	10.892 -11.314
82	75			1.2200+2	11.314 -11.339
83	76			1.1900+2	11.339 -11.373
84	77			1.1500+2	11.373 -11.436
85	78			1.0800+2	11.436 -11.513
86	79	12	10	1.0000+2	11.513 -11.618
87	80			9.0000+1	11.618 -11.711

Table II-2. (cont.)

CSRL-V Group	CSRL Group	27-Group SCALE	16-Group Hansen-Roach	Upper Energy (eV)	Lethargy Range
88	81			8.2000+1	11.711 -11.736
89	82			8.0000+1	11.736 -11.787
90	83			7.6000+1	11.787 -11.841
91	84			7.2000+1	11.841 -11.906
92	85			6.7500+1	11.906 -11.944
93	86			6.5000+1	11.944 -12.007
94	87			6.1000+1	12.007 -12.041
95	88			5.9000+1	12.041 -12.140
96	89			5.3400+1	12.140 -12.167
97	90			5.2000+1	12.167 -12.194
98	91			5.0600+1	12.194 -12.222
99	92			4.9200+1	12.222 -12.241
100	93			4.8300+1	12.241 -12.268
101	94			4.7000+1	12.268 -12.307
102	95			4.5200+1	12.307 -12.334
103	96			4.4000+1	12.334 -12.371
104	97			4.2400+1	12.371 -12.405
105	98			4.1000+1	12.405 -12.439
106	99			3.9600+1	12.439 -12.452
107	100			3.9100+1	12.452 -12.481
108	101			3.8000+1	12.481 -12.507
109	102			3.7000+1	12.507 -12.549
110	103			3.5500+1	12.549 -12.574
111	104			3.4600+1	12.574 -12.599
112	105			3.3750+1	12.599 -12.614
113	106			3.3250+1	12.614 -12.660
114	107			3.1750+1	12.660 -12.676
115	108			3.1250+1	12.676 -12.717
116	109	13	11	3.0000+1	12.717 -12.804
117	110			2.7500+1	12.804 -12.899
118	111			2.5000+1	12.899 -13.005
119	112			2.2500+1	13.005 -13.074
120	113			2.1000+1	13.074 -13.122
121	114			2.0000+1	13.122 -13.174
122	115			1.9000+1	13.174 -13.200
123	116			1.8500+1	13.200 -13.285
124	117			1.7000+1	13.285 -13.346
125	118			1.6000+1	13.346 -13.403
126	119			1.5100+1	13.403 -13.451
127	120			1.4400+1	13.451 -13.497
128	121			1.3750+1	13.497 -13.561
129	122			1.2900+1	13.561 -13.642
130	123			1.1900+1	13.642 -13.676

Table II-2. (cont.)

CSRL-V Group	CSRL Group	27-Group SCALE	16-Group Hansen-Roach	Upper Energy (eV)	Lethargy Range
131	124			1.1500+1	13.676 - 13.816
132	125	14	12	1.0000+1	13.816 - 13.910
133	126			9.1000+0	13.910 - 14.026
134	127			8.1000+0	14.026 - 14.151
135	128			7.1500+0	14.151 - 14.172
136	129			7.0000+0	14.172 - 14.209
137	130			6.7500+0	14.209 - 14.246
138	131			6.5000+0	14.246 - 14.286
139	132			6.2500+0	14.286 - 14.326
140	133			6.0000+0	14.326 - 14.432
141	134			5.4000+0	14.432 - 14.509
142	135			5.0000+0	14.509 - 14.560
143	136			4.7500+0	14.560 - 14.732
144	137			4.0000+0	14.732 - 14.802
145	138			3.7300+0	14.802 - 14.865
146	139			3.5000+0	14.865 - 14.971
147	140			3.1500+0	14.971 - 15.003
148	141	15		3.0500+0[f]	15.003 - 15.019
149	142		13	3.0000+0[g]	15.019 - 15.030
150	143			2.9700+0	15.030 - 15.064
151	144			2.8700+0	15.064 - 15.099
152	145			2.7700+0	15.099 - 15.136
153	146			2.6700+0	15.136 - 15.174
154	147			2.5700+0	15.174 - 15.214
155	148			2.4700+0	15.214 - 15.251
156	149			2.3800+0	15.251 - 15.285
157	150			2.3000+0	15.285 - 15.325
158	151			2.2100+0	15.325 - 15.367
159	152			2.1200+0	15.367 - 15.425
160	153			2.0000+0	15.425 - 15.455
161	154			1.9400+0	15.455 - 15.498
162	155			1.8600+0	15.498 - 15.547
163	156	16		1.7700+0	15.547 - 15.599
164	157			1.6800+0	15.599 - 15.654
165	158			1.5900+0	15.654 - 15.713
166	159			1.5000+0	15.713 - 15.747
167	160			1.4500+0	15.747 - 15.782
168	161			1.4000+0	15.782 - 15.818
169	162			1.3500+0	15.818 - 15.856
170	163	17		1.3000+0	15.856 - 15.895
171	164			1.2500+0	15.895 - 15.915
172	165			1.2250+0	15.915 - 15.936
173	166			1.2000+0	15.936 - 15.957
174	167			1.1750+0	15.957 - 15.978

Table II-2. (cont.)

CSRL-V Group	CSRL Group	27-Group SCALE	16-Group Hansen-Roach	Upper Energy (eV)	Lethargy Range
175	168			1.1500+0	15.978 - 15.987
176	169			1.1400+0	15.987 - 15.996
177	170	18		1.1300+0	15.996 - 16.005
178	171			1.1200+0	16.005 - 16.014
179	172			1.1100+0	16.014 - 16.023
180	173			1.1000+0	16.023 - 16.032
181	174			1.0900+0	16.032 - 16.041
182	175			1.0800+0	16.041 - 16.050
183	176			1.0700+0	16.050 - 16.060
184	177			1.0600+0	16.060 - 16.069
185	178			1.0500+0	16.069 - 16.079
186	179			1.0400+0	16.079 - 16.089
187	180			1.0300+0	16.089 - 16.098
188	181			1.0200+0	16.098 - 16.108
189	182			1.0100+0	16.108 - 16.118
190	183	19	14	1.0000+0	16.118 - 16.143
191	184			9.7500-1	16.143 - 16.169
192	185			9.5000-1	16.169 - 16.196
193	186			9.2500-1	16.196 - 16.223
194	187			9.0000-1	16.223 - 16.281
195	188			8.5000-1	16.281 - 16.341
196	189	20		8.0000-1	16.341 - 16.406
197	190			7.5000-1	16.406 - 16.475
198	191			7.0000-1	16.475 - 16.549
199	192			6.5000-1	16.549 - 16.629
200	193			6.0000-1	16.629 - 16.716
201	194			5.5000-1	16.716 - 16.811
202	195			5.0000-1	16.811 - 16.917
203	196			4.5000-1	16.917 - 17.034
204	197	21	15	4.0000-1	17.034 - 17.099
205	198			3.7500-1	17.099 - 17.168
206	199			3.5000-1	17.168 - 17.242
207	200	22		3.2500-1	17.242 - 17.322
208	201			3.0000-1	17.322 - 17.409
209	202			2.7500-1	17.409 - 17.504
210	203			2.5000-1	17.504 - 17.610
211	204	23		2.2500-1	17.610 - 17.728
212	205			2.0000-1	17.728 - 17.861
213	206			1.7500-1	17.861 - 18.015
214	207			1.5000-1	18.015 - 18.198
215	208			1.2500-1	18.198 - 18.421
216	209	24	16[e]	1.0000-1	18.421 - 18.526
217	210			9.0000-2	18.526 - 18.644
218	211			8.0000-2	18.644 - 18.777

Table II-2. (cont.)

CSRL-V Group	CSRL Group	27-Group SCALE	16-Group Hansen-Roach	Upper Energy (eV)	Lethargy Range
219	212			7.0000-2	18.777 - 18.932
220	213			6.0000-2	18.932 - 19.114
221	214	25		5.0000-2	19.114 - 19.337
222	215			4.0000-2	19.337 - 19.625
223	216	26		3.0000-2	19.625 - 19.795
224	217			2.5300-2	19.795 - 20.723
225	218[c]	27[d]		1.0000-2	20.723 - 23.
226				1.0000-3	23.026 - 25.328
227[b]				1.0000-4	25.328 - 27.631

[a] Read, 2.0000x10^{7}.

[b] Bottom energy for CSRL-V Group 227 is 1.0000x10^{-5} eV.

[c] Bottom energy for CSRL Group 218 is 1.0000x10^{-5} eV.

[d] Bottom energy for SCALE Group 27 is 1.0000x10^{-5} eV.

[e] Bottom energy for Hansen-Roch Group 16 is 1.0000x10^{-3} eV.

[e] Top energy of the CSRL thermal energy range.

[g] Top energy of the CSRL-V thermal energy range.

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The CSRL-V group structure includes 79 thermal groups in the 10^{-5} to 3.00 eV range to accommodate the effects of low-energy resonance and thermal-neutron upscatter. The 148 groups in the 3-eV to 20-MeV range permit fine-group consideration of the resonance structure of prominent nuclei, the thresholds of important reactions, and various fission spectra. Specifically, the boundaries were chosen to fit the reaction thresholds and major resonance levels of the following nuclides: Be, B-10, C, N, O, F, Na, Mg, Al, Si, K, Ca, Cr, Mn, Fe, Ni, Cu, Zr, Mo, Ag, Col, In, Sn, Ba, Gd, Hf, Pb, Th-232, U-233, U-234, U-235, U-236, U-238, Pu-238, Pu-239, Pu-240, and Pu-241.

Of the 148 epithermal groups, 58 groups span the fission-neutron-energy range from 20 MeV to 8.03 keV. This energy range includes most of the cross-section structure for the light and intermediate-mass nuclides. It also includes inelastic scattering and fission thresholds for certain of the heavy nuclides. The 90 groups between 8.03 keV and 3.00 eV were chosen to bracket major resonance levels in the intermediate-mass and heavy nuclides.

In the thermal energy range, several of the fuel and neutron absorbing nuclides have large resonances which are broad relative to the neutron energy exchange per collision. The 79 closely spaced thermal groups are designed to account for the effects of those resonances in the presence of thermal upscatter. Criteria used in the selection of energy boundaries in both the thermal and epithermal ranges are listed in Appendix A.

All materials in the 227-group CSRL-V library were processed with a fission-1/E-Maxwellian weighting function. Temperature of the fission spectrum component of the weighting function was 1.27×10^6 eV; temperature of the Maxwellian component was 300 K. As shown in the footnotes of Table II-2, the energy at which the fission component was joined to the 1/E component generally was 1.4 MeV for the light materials, 0.75 MeV for the intermediate-mass materials, and 0.1 MeV for the heavy materials. The 1/E component was joined to the Maxwellian component at 0.1265 eV for the processing of all materials. The multigroup representation of the fission-1/E-Maxwellian spectrum used to prepare the master data sets for the heavy materials is shown in Fig. II-1.

II.C CODES USED TO PROCESS CSRL-V DATA

Current in-house versions of modules (codes) from the AMPX[3] and NJOY cross-section processing systems were used to process CSRL-V. Modules used in the standard procedure to process the data are shown in Fig. II-2. The function of each of the modules is as follows:

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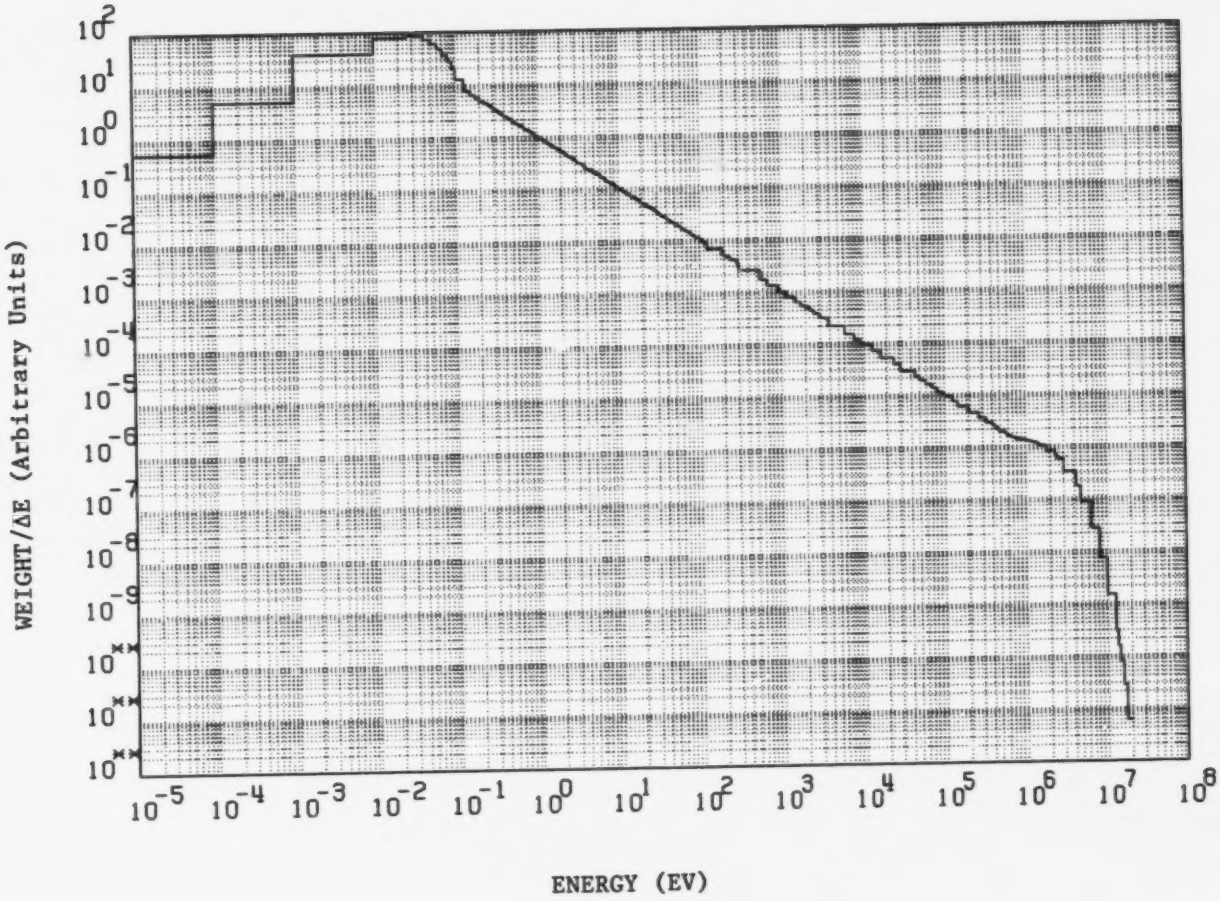

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Fig. II-1. Fission-1/E-Maxwellian Weight Functions

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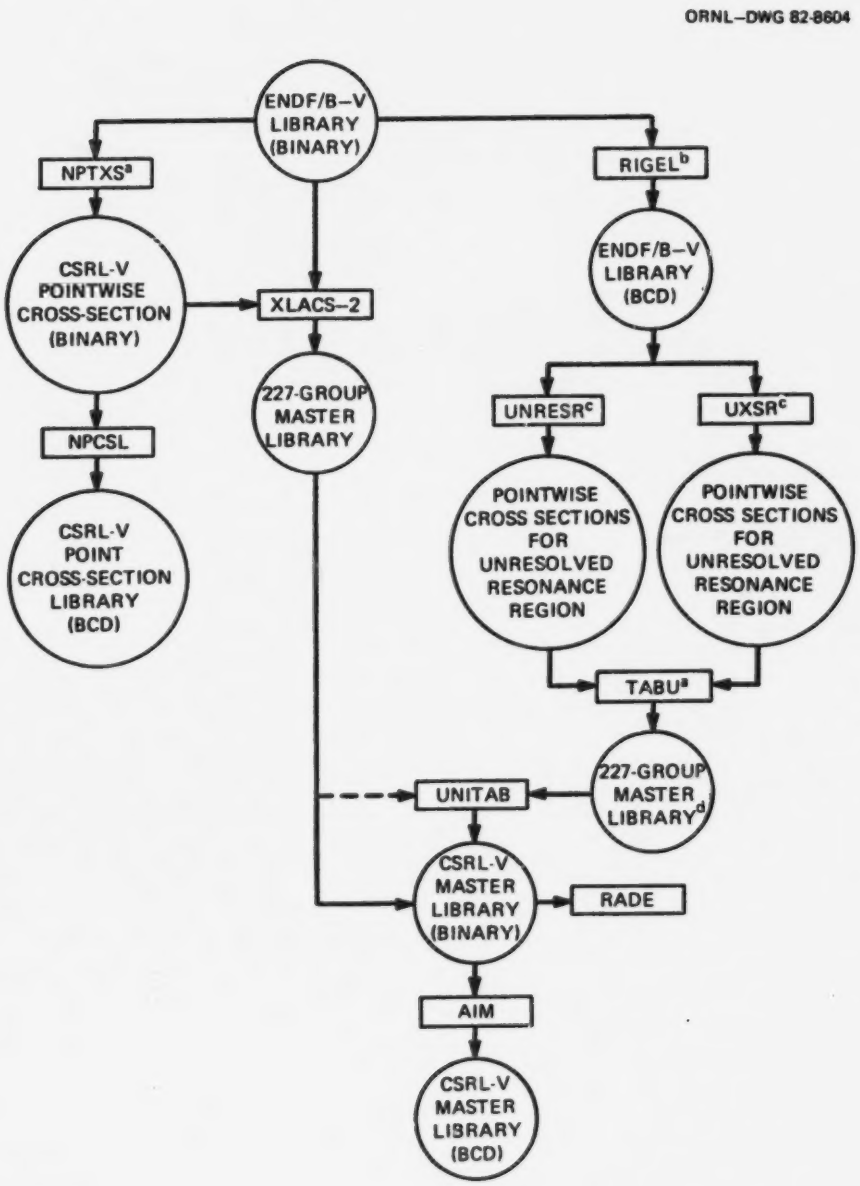

[a]AMPX MODULE
[b]ENDF PROCESSING CODE
[c]NJOY MODULE
[d]CONTAINS ONLY BONDARENKO FACTOR DATA FOR THE UNRESOLVED ENERGY REGION.

Figure II-2. Codes Used to Generate CSRL-V Libraries

NPTXS - This AMPX module "preprocesses" resonance or nonresonance ENDF evaluations to make point files (i.e., neutron energy, cross-section pairs) for the total, fission, elastic scattering, and (n,γ) cross sections — the CSRL-V Pointwise Library. Pointwise data are used to augment the ENDF data selected in an XLACS-2 calculation to calculate the elastic scattering matrices. Additional characteristics of the pointwise library are described in Chapter III.

NPCSL - This code is used to convert the binary pointwise library to BCD format.

XLACS-2 - This AMPX module is used to produce full-energy-range multigroup neutron cross sections in AMPX master format. The module processes ENDF/B resolved resonance data into a form suitable for use (i.e., resonance parameters) in the calculation of self-shielded cross sections with the Nordheim integral treatment provided in the NITAWL (AMPX) module.

RIGEL[21] - This ENDF code is used to change the mode of the ENDF/B-V library from binary to BCD, or vice versa.

UNRESR - This NJOY module[22] computes effective pointwise self-shielded cross sections for the unresolved resonance region.

UXSR - This NJOY module is an improved version of the UNRESR module.

TABU - An AMPX module for generating an AMPX master cross-section file which only contains Bondarenko factor data for the nuclide-dependent unresolved energy region. The module processes pointwise "average" cross-section data. These "average" data are a function of material, process, temperature, sigma-0 (a parameter commonly used with Bondarenko data), and energy. An input smooth weighting spectrum is used to convert the pointwise data to group-averaged Bondarenko data.

UNITAB - This AMPX module merges selected data from various input master data sets into a new master data set.

RADE - This AMPX module makes first order checks on AMPX master, AMPX working, and ANISN-formatted multigroup libraries.

AIM - This AMPX module converts binary master libraries to BCD-formatted master libraries, or vice versa.

II.D FORMAT OF THE CSRL-V MASTER LIBRARY

Among the many types of cross-section libraries that can be generated with the AMPX system (libraries such as ANISN-formatted libraries, CCCC-formatted libraries, "working" libraries, etc.), the

format of an AMPX master cross-section library, i.e., the format of the CSRL-V 227-group library, is the most general way to store multigroup neutron cross-section data. Included in a master library are one-dimensional multigroup cross-section data, transfer matrices for elastic and inelastic scattering reactions and for neutron producing reactions [e.g., (n,2n)] with arbitrary orders of scatter for fast and thermal data where required, resonance self-shielding parameters (including Bondarenko factors) for subsequent problem-dependent processing, fission spectrum data, weighting function data, etc. These data are available in a compacted magic word format to remove extraneous zeros and consequently to substantially reduce tape storage requirements. Format of an AMPX master library is given in Appendix B.

II.E. CONTENTS OF THE CSRL-V MASTER LIBRARY

Materials in the fine-group CSRL-V AMPX master library are listed in Table II-1. One-dimensional and transfer matrix data (two-dimensional data) in each data set are identified by MT number in the table.[a] The MT number-reaction relations are identified in Appendix C. A DIAL-produced table of contents for data sets in the CSRL-V master library is given on the microfiche affixed to the back cover of this report. (DIAL is an AMPX module which produces edits of AMPX master or working libraries.) The table of contents contains the following information for each data set:

Data set ID number

Title card information

Number of records in the data set

Number of resolved resonances

Number of unresolved resonance points

Number of temperature-independent one-dimensional neutron processes

Number of temperature-dependent one-dimensional neutron processes

Number of one-dimensional gamma-ray processes (zero for CSRL-V data sets)

Number of two-dimensional gamma-ray processes (zero for CSRL-V data sets)

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[a] It is assumed that the reader is familiar with the ENDF nomenclature described in Ref. 1.

Number of neutron-to-gamma processes (zero for CSRL-V data sets)

Maximum order P_n

Mass (neutron equivalent) of the nuclide

ZA number of the nuclide

Number of words in the longest two-dimensional array

Number of Bondarenko processes

Number of Bondarenko sigma zeros

Number of Bondarenko temperatures

Number of Bondarenko groups

ENDF MAT of fast neutron data

ENDF MAT of thermal neutron data

MT numbers of one-dimensional neutron data

MT numbers of two-dimensional neutron data

Comments relating to resolved resonance, unresolved resonance, and thermal range processing, the fission spectrum in appropriate CSRL-V data sets, elastic scattering processing, and special CSRL-V master data sets are given in Sections II.E.1-II.E.6, respectively.

II.E.1 Resolved Resonance Processing[a]

For ENDF/B-V evaluations which contain resolved resonance data (see Table II-1), XLACS-2 processed the resonance data into a form suitable for use in the calculation of self-shielded cross sections with the Nordheim integral treatment[23] provided in the WITAWL module of the AMPX system. The XLACS-2 processing involves the calculation of two arrays of cross-section data for the elastic scattering, n-γ capture, and fission reactions, i.e., XLACS-2 calculates MT 2 and 1023 data for elastic scattering, MT 18 and 1022 data for fission, and MT 102 and 1021 data for n-γ capture. The MT 1021, 1022, and 1023 arrays contain the averaged values of the cross sections for

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[a] This section is taken from Chapter 3 of Ref. 3.

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the resonance bodies. These averaged values are weighted over the weighting spectrum specified for the XLACS-2 problem. (If a 1/E weighting spectrum is used in the resolved region, the MT 1021, 1022, and 1023 data are "infinite dilution" data.)

The MT 18 and MT 102 arrays contain "everything" except the MT 1021 and MT 1022 data, respectively. "Everything" includes the following:

a. The wings of the resonances (recall that the Nordheim treatment only applies to a region close to the resonance peak).

b. The contributions from all ℓ=1, 2, 3, . . . resonances.

c. The interference terms (even in the resonance body) for the case of multilevel Breit-Wigner fits.

d. The ENDF File 3 background data.

Conversely, the calculated MT 2 data are the sum of the above "everything" contributions and the 1023 data, i.e., the MT 2 data are for total elastic scattering.

Data calculated for MT 1, 27, and 101 follow the same rules as for MT 2, 18, and 102. For example,

$$(\text{MT } 27) = (\text{MT } 101) + (\text{MT } 18) \tag{1}$$

$$(\text{MT } 101) = \sum_{i=2}^{14} (\text{MT } 100+i) \tag{2}$$

II.E.2 Unresolved Resonance Processing

Resonance materials containing unresolved parameters in the ENDF File 2 data were processed with a RIGEL-UNRESR (or UXSR)-TABU-UNITAB sequence to provide Bondarenko factor data[24] for the nuclide-dependent unresolved energy region. The materials which were processed with this sequence and the nuclide-dependent processes, temperatures, sigma-0's, and energy range for the Bondarenko factors are identified in Table II-1. Problem-dependent resonance self-shielded cross sections for the Bondarenko factor energy ranges should be processed with the BONAMI-2 AMPX module.

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II.E.3 Thermal Range Processing

A feature of the code used to process the CSRL-V multigroup data (XLACS-2) is the ability to process normal ENDF/B data in the fast and epithermal energy regions and to couple the data in a consistent fashion with thermal data taken from another ENDF/B evaluation to produce a single full-energy-range master data set. This means, for example, that a multithermal-group master data set can be prepared for hydrogen using the normal ENDF/B hydrogen evaluation for the energy region above the thermal-epithermal cutoff, i.e., for the fast groups, and using an ENDF thermal evaluation containing $S_{\alpha,\beta}$ data based on a water model for the region below the cutoff energy (the thermal groups). Two advantages of this approach are the convenience of dealing with a single set of processed data and the generation of multigroup cross sections representing the correct distributions for neutrons elastically or inelastically scattered into the thermal range. This procedure was used to process water-bound and polyethylene-bound hydrogen, CSRL-V ID's 1001 and 1301, respectively, and D_2O-bound deuterium (1002).

Only the very light moderators need the special ENDF thermal evaluations for the preparation of multithermal-group cross sections. For those nuclides which have no special thermal evaluations, XLACS-2 allows the following options for generating thermal scattering matrices based on the free gas treatment:

1. The code will generate free gas $S_{\alpha,\beta}$ data. This process was used with light nuclides -- $A \leq 19$.

2. The code will use an analytic free gas treatment to generate P_0 thermal matrices. The thermal values are normalized to the free-atom scattering cross section in the epithermal range. This process was used for nuclides with mass > 19 and with no resonances in the thermal range.

3. The same analytic routines used in #2 are used but the scattering matrices are normalized to the average values of the scattering cross section in the thermal range. (Note that this will not preserve the Doppler broadening inherent in the free gas equations unless it is present in the thermal point values.) This approach was used for nuclides with thermal resonances -- nuclides such as ^{235}U and ^{240}Pu.

II.E.4 Fission Spectrum

XLACS-2 calculates a full group-to-group fission matrix as a prelude to calculating an averaged fission spectrum. This two-dimensional array is reduced to the one-dimensional array placed on the master library (MT 1018) by the following expression:

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$$\bar{\chi}_g = \frac{\sum_{g'} \nu_{g'} \sigma^f_{g'} \phi_{g'} \chi(g' \rightarrow g)}{\sum_{g'} \nu_{g'} \sigma^f_{g'} \phi_{g'}} \qquad (3)$$

II.E.5 Elastic Scattering Cross-Section Processing

Two options are available in XLACS-2 for processing elastic scattering data (MT 2 data) for resonance materials. The more accurate procedure, which requires a previously generated pointwise library containing MT 2 data, was used to process the CSRL-V elastic scattering matrices. Characteristics of the pointwise library used to process the data are described in Chapter III.

II.E.6 Special CSRL-V Data Sets

Some data sets in the CSRL-V library were processed with nonstandard procedures. These data sets are described below:

1/V Data (ID 999) - Data set 999 contains 1/V cross sections, weighted with a fission-1/E-Maxwellian spectrum, and normalized to unity at 0.0253 eV. The master data set was generated by using the AMPX modules JERK to provide a two-point 1/V function, JERGENS to provide a 1000-point representation of weighting spectrum "B" (see Table II-1 footnotes), and VEL to fold the 1/V and weighting functions, normalize and multigroup the data, and place the data in the required AMPX master format.

Graphite (ID 6312) - Data set 6312 is carbon (MAT 1306) with a graphite thermal scattering kernel (1065). The data were processed with the NJOY system. The graphite kernel has scattering matrices at five temperatures, viz., 296, 500, 800, 1200, and 2000 K. The thermal scattering matrices occur in two parts, an elastic part and an inelastic part. All scattering matrices are P_5 except for the inelastic continuum matrix (MT=91 which is P_0). Although MAT 1306 does not contain unresolved (or resolved) resonance data, NJOY calculated Bondarenko factor data for the temperatures, the sigma-0, and MT's shown in Table II-1. The factors span the full CSRL-V energy range. Problem-dependent cross sections for the lowest temperature (296 K) can be prepared without a BONAMI-2 step. Conversely, preparation of problem-dependent cross sections for $296 > t \geq 2000$ K must include a BONAMI-2 step.

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Zircaloy-2 (ID 40302) - Using the recipe given in the File 1 data for ENDF/B-IV MAT 1284, a CSRL-V master data set for Zircaloy-2 was prepared (approximated) by: (1) normalizing the ID 999 1/V data to 0.024 barns at 2200 m/s, (2) defining the resulting 1/V data as a capture cross section, and (3) adding the data to the Zr data set (40000). The resulting data set was assigned an ID number of 40302.

Neutron Dose Factors (ID 500000) - This CSRL-V data set contains neutron dose factor sets processed from the collection of dose factor data in the "old" XLACS module and an ANSI standard dose factor set. The dose factors were weighted with the "B" fission-1/E-Maxwellian weighting function defined in Table II-1 and placed into master library format with an XLACS-JERGENS-VEL calculational sequence. The resulting CSRL-V data set (500000) contains the one-dimensional cross sections, i.e., dose factor sets, identified in Table II-3.

II.F. FIRST ORDER CHECKS OF THE CSRL-V MASTER DATA

Data in the CSRL-V master library were checked for first-order consistencies with the RADE module of the AMPX system. RADE made the following checks:

$$\sigma_T \stackrel{?}{=} \sigma_a + \sigma_s \tag{4}$$

$$\sigma_{in} \stackrel{?}{=} \Sigma^{\text{partial}} \sigma_{in} \tag{5}$$

$$\sigma_a \stackrel{?}{=} \sigma_c + \sigma_f \tag{6}$$

$$\sigma_c \stackrel{?}{=} \sigma_{n\gamma} + \sigma_{n\alpha} + \sigma_{np} + \sigma_{nd} + \cdots \tag{7}$$

$$\sigma^g_{e\ell} \stackrel{?}{=} \sum_{g'} \sigma_{e\ell,0}\,(g \to g') \tag{8}$$

$$\sigma_0(g \to g') \stackrel{?}{\geq} 0 \tag{9}$$

$$\sigma_T,\ \sigma_a,\ \sigma_f,\ \sigma_{n\gamma},\ \sigma_{np},\ \ldots \stackrel{?}{\geq} 0 \tag{10}$$

$$-1 \stackrel{?}{\leq} \bar{\mu}(g \to g') = \left(\frac{\sigma_1(g \to g')}{3\sigma_0(g \to g')} \right) \stackrel{?}{\leq} 1 \tag{11}$$

Table II-3. Dose Factor Sets in CSRL-V Master Data Set 500000

One-Dimensional Cross-Section MT Number	Dose Factor Identification
9001	Hurst
9002	Snyder-Newfeld
9003	Conversion factors for neutron displacement in silicon
9004	Conversion factors for neutron ionization in silicon
9005	Unclassified thermonuclear source spectrum
9012	TSR-II source spectrum at end of collimator
9013	14 MeV source spectrum
9014	Response function for 2.06-Inch-Diameter Bonner Sphere
9015	Response function for 3.00-Inch-Diameter Bonner Sphere
9016	Response function for 3.09-Inch-Diameter Bonner Sphere
9017	Response function for 3.94-Inch-Diameter Bonner Sphere
9018	Response function for 4.03-Inch-Diameter Bonner Sphere
9019	Response function for 5.02-Inch-Diameter Bonner Sphere
9020	Response function for 5.88-Inch-Diameter Bonner Sphere
9021	Response function for 6.00-Inch-Diameter Bonner Sphere
9022	Response function for 7.86-Inch-Diameter Bonner Sphere
9023	Response function for 9.86-Inch-Diameter Bonner Sphere
9024	Response function for 11.84-Inch-Diameter Bonner Sphere
9025	Response function for modified 3.00-Inch-Diameter Bonner Sphere
9026	Snyder-Neufeld conversion from (mrems/h)/(neut./cm^2-s) flux to biological dose
9027	Henderson conversion from flux (rd/h)/(neut./cm^2-s) to absorbed dose rate in tissue
9029	American National Standard (rem/h)/(neut./cm^2-s) neutron flux-to-dose rate factor

When making the above data checks, RADE was triggered to use a checking tolerance of 0.1%. Results of the data tests are included on the microfiche attached to the back cover of this report.

II.G. IMPLEMENTING AND USING THE CSRL-V MASTER LIBRARY

To facilitate transfer of master libraries between computing installations, RSIC distributes BCD-formatted libraries. Use of the BCD-formatted CSRL-V library with the AMPX system first requires a conversion of the library to binary format. The AIM module of RSIC's AMPX package can be used to make the format conversion.

Given the CSRL-V master library, the capabilities of the AMPX system can be used to accomplish the following cross-section related tasks:

1. ENDF/B-V photon-production data and ENDF-formatted gamma-interaction data can be processed into multigroup master data sets and combined with the appropriate CSRL-V data sets to give a pseudo-problem-independent coupled neutron-gamma master cross-section library (a LAPHNGAS-SMUG-CHOX sequence).

2. CSRL-V resolved resonance and infinite-dilute unresolved resonance data can be self-shielded with the Nordheim integral treatment (NITAWL) and the unresolved resonance Bondarenko factor data can be self-shielded with the BONAMI-2 module to give problem-dependent data.

3. For problems in which either resonance overlap causes mutual shielding or spatial attenuation of the neutron flux indicates the need for spatially dependent resonance cross sections, the CSRL-V master and pointwise libraries can be used in the execution of an integral transport calculation for the energy-pointwise, slowing-down flux distribution in each zone of a one-dimensional, multiregion geometry (ROLAIDS). The resulting resonance-shielded fine-group constants can be folded into the CSRL-V master data sets to give problem-dependent data (CLAROL).

4. Using either previously prepared multigroup spectra or the fine-group representation of the weighting spectrum in each CSRL-V data set (MT 1099 data) as collapsing spectra, the master data sets can be spectrally collapsed to a broad-group subset of the 227-group structure (MALOCS).

5. One-dimensional discrete ordinates, one-dimensional diffusion, or infinite medium transport theories can be used with the CSRL-V master library to calculate system-dependent spectra, to

flux weight cross-sections, and to collapse the fine-group data to a broad-group subset of the 227-group structure (BONAMI-2-NITAWL-XSRDNPM).

6. Various AMPX modules can be used to convert the CSRL-V master library data to formats required for many transport codes, e.g.

Cross-Section Format	Typical AMPX Sequence	Format Used with Transport Codes
AMPX Working	BONAMI2 - NITAWL or BONAMI2 - NITAWL - XSDRNPM	KENO, XSDRNPM
ANISN	BONAMI2 - NITAWL or BONAMI2 - NITAWL - XSDRNPM	ANISN, DOT, MORSE, SWANLAKE
CCCC	BONAMI2 - NITAWL - XSDRNPM	VENTURE

7. CSRL-V data can be used with AMPX service function modules to edit (DIAL), punch one- or two-dimensional cross-section data (PAL), manage data (AJAX), modify data (CLAROL), prepare macroscopic data (working formatted data ICE2), etc.

As implied by the preceding discussion, the modularity of the AMPX system enables one to process the CSRL-V data in many ways. Many hints for using master cross-section libraries, including sample problems, are given in RSIC's AMPX-II documentation.

III. CSRL-V POINTWISE CROSS-SECTION LIBRARY

The NPTXS module of the AMPX system was used to generate a pointwise cross-section library containing total, fission (where available), elastic scattering, and (n,γ) cross sections for the resonance materials processed for the CSRL-V master library. This step provided the pointwise MT 2 data needed for the XLACS-2 elastic scattering data processing (see Section II.E.5 above). The resulting collection of pointwise data is identified as the CSRL-V pointwise cross-section library. Contents of the library are listed in Table III-1.

Basic sources of the evaluated data processed for the library are the same as those listed for the master library - see Table II-1. Doppler broadening in the resolved and unresolved resonance regions was done for a temperature of 296 k. A potential scattering cross section of 5×10^4 barns/atom was used in the unresolved resonance processing.

Reaction-type pointwise data and the number of energy-cross-section points in each data set in the library are identified in Table III-1. The CSRL-V library is written "very much like" File 3 of an ENDF library.

Table III-1. CSRL-V Pointwise Cross-Section Library

Nuclide	ZA No.	Pointwise Data Set ID No.	Pointwise Data	
			MT No.	No. Points
^{23}Na	11023	1311	1	1524
			2	1657
			102	1464
Cr	24000	1324	1	7726
			2	7519
			102	7939
^{55}Mn	25055	1325	1	6972
			2	6718
			102	8564
Fe	26000	1326	1	12641
			2	11626
			102	19800
^{59}Co	27059	1327	1	8070
			2	7694
			102	9710
Ni	28000	1328	1	7833
			2	7663
			102	7021
Cu	29000	1329	1	4234
			2	4207
			102	3213
^{78}Kr	36078	1330	1	428
			2	413
			102	469
^{80}Kr	36080	1331	1	567
			2	559
			102	559
^{82}Kr	36082	1332	1	220
			2	211
			102	221
^{83}Kr	36083	1333	1	349
			2	354
			102	437
^{84}Kr	36084	1334	1	387
			2	365
			102	444
^{86}Kr	36086	1336	1	217
			2	203
			102	216

Table III-1 (cont.)

Nuclide	ZA No.	Pointwise Data Set ID No.	Pointwise Data	
			MT No.	No. Points
Zr	40000	1340	1	4191
			2	3998
			102	5087
^{90}Zr	40090	1385	1	1555
			2	1553
			102	1713
^{91}Zr	40091	1386	1	1630
			2	1487
			102	1902
^{92}Zr	40092	1387	1	1767
			2	1787
			102	1848
^{94}Zr	40094	1388	1	2083
			2	2070
			102	2270
^{96}Zr	40096	1389	1	1679
			2	1710
			102	1870
^{93}Nb	41093	1189	1	7929
			2	5701
			102	10957
Mo	42000	1321	1	2264
			2	1548
			102	3403
^{99}Tc	43099	1308	1	2826
			2	1773
			102	4248
^{103}Rh	45103	1310	1	4181
			2	2695
			102	6415
^{107}Ag	47107	1371	1	2586
			2	1944
			102	3520
^{109}Ag	47109	1373	1	3326
			2	2644
			102	4138
^{113}Cd	48113	1318	1	1593
			2	1276
			102	2108
^{124}Xe	54124	1335	1	503
			2	498
			102	557

Table III-1 (cont.)

Nuclide	ZA No.	Pointwise Data Set ID No.	Pointwise Data	
			MT No.	No. Points
^{126}Xe	54126	1339	1	438
			2	437
			102	482
^{128}Xe	54128	1348	1	959
			2	955
			102	1085
^{129}Xe	54129	1349	1	5208
			2	5081
			102	5580
^{130}Xe	54130	1350	1	1102
			2	1094
			102	1247
^{131}Xe	54131	1351	1	3174
			2	3095
			102	3501
^{132}Xe	54132	1352	1	411
			2	415
			102	479
^{134}Xe	54134	1354	1	191
			2	177
			102	330
^{133}Cs	55133	1355	1	5860
			2	5023
			102	7374
^{149}Sm	62149	1319	1	4129
			2	3699
			102	4189
^{151}Eu	63151	1357	1	5466
			2	4121
			102	5699
^{152}Eu	63152	1292	1	4938
			2	3431
			102	5055
^{153}Eu	63153	1359	1	4397
			2	3089
			102	4583
^{154}Eu	63154	1293	1	4161
			2	2671
			102	4362
^{152}Gd	64152	1362	1	1691
			2	1624
			102	1691

Table III-1 (cont.)

Nuclide	ZA No.	Pointwise Data Set ID No.	Pointwise Data	
			MT No.	No. Points
^{154}Gd	64154	1364	1	3594
			2	3420
			102	3775
^{155}Gd	64155	1365	1	5669
			2	4381
			102	5910
^{156}Gd	64156	1366	1	1793
			2	1824
			102	1898
^{157}Gd	64157	1367	1	3797
			2	3392
			102	3940
^{158}Gd	64158	1368	1	6836
			2	6637
			102	7182
^{160}Gd	64160	1370	1	3691
			2	3660
			102	3874
^{164}Dy	66164	1031	1	1503
			2	1293
			102	1539
^{175}Lu	71175	1032	1	288
			2	255
			102	305
^{176}Lu	71176	1033	1	1863
			2	1482
			102	1903
Hf	72000	1372	1	7719
			2	6039
			102	9024
^{174}Hf	72174	1374	1	997
			2	1052
			102	1035
^{176}Hf	72176	1376	1	2002
			2	2003
			102	2095
^{177}Hf	72177	1377	1	5504
			2	4553
			102	5959
^{178}Hf	72178	1378	1	2248
			2	2242
			102	2366

Table III-1 (cont.)

Nuclide	ZA No.	Pointwise Data Set ID No.	Pointwise Data	
			MT No.	No. Points
^{179}Hf	72179	1383	1	3456
			2	3163
			102	3679
^{180}Hf	72180	1384	1	2924
			2	2960
			102	3147
^{181}Ta	73181	1285	1	4058
			2	3291
			102	4489
^{182}Ta	73182	1127	1	919
			2	661
			102	991
^{182}W	74182	1128	1	5223
			2	5186
			102	5555
^{183}W	74183	1129	1	3606
			2	3488
			102	3869
^{184}W	74184	1130	1	2792
			2	2758
			102	3036
^{186}W	74186	1131	1	3000
			2	3008
			102	3236
^{185}Re	75185	1083	1	2185
			2	1617
			102	2352
^{187}Re	75187	1084	1	1731
			2	1366
			102	1894
^{197}Au	79197	1379	1	13817
			2	12864
			102	16586
^{232}Th	90232	1390	1	11339
			2	8758
			18	14511
			102	13956
^{233}Pa	91233	1391	1	2751
			2	1362
			18	84
			102	2933

Table III-1 (cont.)

Nuclide	ZA No.	Pointwise Data Set ID No.	Pointwise Data	
			MT No.	No. Points
^{233}U	92233	1393	1	2185
			2	2185
			18	2185
			102	2185
^{234}U	92234	1394	1	5224
			2	4756
			18	5740
			102	5925
^{235}U	92235	1395	1	4780
			2	2215
			18	5240
			102	5781
^{236}U	92236	1396	1	8921
			2	8573
			18	9503
			102	9470
^{238}U	92238	1398	1	13185
			2	9207
			18	3030
			102	17931
^{237}Np	93237	1337	1	6774
			2	3494
			18	7598
			102	7797
^{238}Pu	94238	1338	1	1218
			2	1026
			18	1294
			102	1355
^{239}Pu	94239	1399	1	5231
			2	3930
			18	5319
			102	6088
^{240}Pu	94240	1380	1	9479
			2	8869
			18	10226
			102	9705
^{241}Pu	94241	1381	1	3385
			2	3385
			18	3385
			102	3385

Table III-1 (cont.)

Nuclide	ZA No.	Pointwise Data Set ID No.	Pointwise Data	
			MT No.	No. Points
^{242}Pu	94242	1342	1	3126
			2	2872
			18	2174
			102	3607
^{241}Am	95241	1361	1	3892
			2	1823
			18	4337
			102	4205
^{242}Am	95242	1369	1	211
			2	133
			18	194
			102	227
^{243}Am	95243	1363	1	8657
			2	5260
			18	56
			102	9673
^{243}Cm	96243	1343	1	952
			2	651
			18	932
			102	1020
^{244}Cm	96244	1344	1	2347
			2	2216
			18	2571
			102	2546
^{245}Cm	96245	1345	1	336
			2	167
			18	315
			102	319
^{246}Cm	96246	1346	1	858
			2	874
			18	1064
			102	1048

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APPENDIX A

Criteria Used in the Selection of CSRL-V Group Boundaries

Criteria used in the selection of boundaries for the 227-group energy structure are listed in Table A.1. (The 227-group energy structure is listed in Table II-2.) Various versions of BNL-325,[25-32] ENDF-200,[33] and the ENDF/B data were sources of the criteria. Information in Table A.1 can be used to identify cross-section structure by nuclide and thereby aid in the selection of broad-group structures from the 227-group set. Thresholds and resonance regions are identified by reaction type down to approximately 500 eV. Below 500 eV, individual levels are not identified by reaction type since they may exhibit significant scatter, capture and/or fission.

Table A.1. Criteria for Selection of the 148 Epithermal Group Boundaries

Energy (eV)	Criterion
20+6[a]	ENDF/B-V upper cutoff
6.43+6	O - inelastic threshold
4.8+6	C - inelastic threshold
4.30+6	N - n, threshold
3+6	Hansen-Roach boundary
2.479+6	N - inelastic threshold
2.354+6	O - n,α threshold B-10 - upper bound on 1.9 MeV (.4b) n,α level
1.85+6	Be - n,2n threshold
1.5+6	U-238 - fission plateau B-10 - lower bound on 1.9 MeV (.4b) n,α level
1.4+6	Hansen-Roach boundary
1.356+6	Ni - inelastic threshold O - upper bound on 1.312 MeV (6b) n,n' level Mg - inelastic threshold (1.34 MeV)

Table A.1 (cont.)

Energy (eV)	Criterion
1.317+6	Si - inelastic threshold
1.25+6	B-10 - inelastic threshold O - lower bound on 1.312 MeV (6b) n,n' level
1.2+6	Th-232 - fission threshold B-10 - n,t threshold Ca - inelastic threshold (1.187 MeV)
1.1+6	O - upper bound on 1 MeV (8b) n,n' level
1.01+6	K - inelastic threshold Pu-240 - fission plateau
9.20+5	Zr - inelastic threshold
9.00+5	Hansen-Roach boundary O - lower bound on 1 MeV (8b) n,n' level
8.75+5	Al - inelastic threshold Si - upper bound of 805 KeV (7.5b) n,n' level
8.611+5	Fe - inelastic threshold
8.20+5	Be - upper bound of 810 KeV (5.3b) n,n' level
8.00+5	Be - lower bound of 810 KeV (5.3b) n,n' level
7.50+5	Na - upper bound of 710 KeV (8b) n,n' level Si - lower bound of 805 KeV (7.5b) n,n' level
6.79+5	Cu - inelastic threshold
6.70+5	Be - n,α threshold Be - upper bound of 620 KeV (7.5b) n,n' level Na - lower bound of 710 KeV (8b) n,n' level
6.00+5	U-236 - fission threshold Be - lower bound of 620 KeV (7.5b) n,n' level Si - upper bound of 570 KeV (7.8b) n,n' level
5.73+5	Pb - inelastic threshold Cr - inelastic threshold (575.1 KeV) Mg - inelastic threshold (584 KeV)

Table A.1 (cont.)

Energy (eV)	Criterion
5.50+5	Si - lower bound of 570 (7.8b) n,n' level
4.9952+5	Fe - n,p threshold O - upper bound on 442 KeV (17b) n,n' level
4.70+5	Na - inelastic threshold Mg-24 - upper bound on 430 KeV (12b) n,n' level
4.40+5	N - upper bound on 432 KeV (6.5b) n,n' level
4.20+5	N - lower bound on 432 KeV (6.5b) n,n' level
4.00+5	Hansen-Roach boundary O - lower bound on 442 KeV (17b) n,n' level Mg-24 - lower bound on 430 KeV (12b) n,n' level
3.30+5	Mg-24 - upper bound on 275 KeV (13b) n,n' level
2.70+5	Si - upper bound on 200 KeV (11b) n,n' level Cd-113 - inelastic threshold
2.00+5	Mo - inelastic threshold Mg-24 - lower bound on 275 KeV (13b) n,n' level
1.50+5	Si - lower bound on 200 KeV (11b) n,n' level Cr-52 - upper bound on 138 KeV (10b) n,n' level
1.283+5	Mn-55 - inelastic threshold F - upper bound of 100 KeV (26b) n,n' level Cr-52 - lower bound on 138 KeV (10b) n,n' level and upper bound of 95 KeV (18b) n,n' level Mg - upper bound on 81 KeV (Mg-25) and 85 KeV (Mg-24,45b) n,n' levels
1.00+5	Hansen-Roach boundary Al - upper bound on 89 KeV (18b) n,n' level
8.5+4	Fe - upper bound on 83.7 KeV (27b) n,n' level Cr-52 - lower bound on 95 KeV (18b) n,n' level
8.2+4	Fe - lower bound on 83.7 KeV (27b) n,n' level Al - lower bound on 89 KeV (18b) n,n' level F - lower bound on 100 KeV (26b) n,n' level

Table A.1 (cont.)

Energy (eV)	Criterion
7.5+4	Fe - upper bound on 74 KeV (22b) n,n' level
7.3+4	Fe - lower bound on 74 KeV (22b) n,n' level
6.0+4	Gd - inelastic threshold Mg - lower bound on 81 KeV (Mg-25) and 84 KeV (Mg-24,45b) n,n' levels Na - upper bound on 55 KeV (10b) n,n' level Al - upper bound on 35.04 KeV (34b) n,n' level Cr-52 - upper bound on 51 KeV (25b) n,n' level
5.2+4	F - upper bound on 49.7 KeV (30b) n,n' level
5.0+4	U-238 - fission threshold Th-232 - inelastic threshold (50.2 KeV) Pu-240 - fission threshold Na - lower bound on 55 KeV (10b) n,n' level
4.5+4	F - lower bound on 49.7 KeV (30b) n,n' level Cr-52 - lower bound on 51 KeV (25b) n,n' level U-236 - inelastic threshold (46 KeV) U-238 - inelastic threshold (44.9 KeV) U-234 - inelastic threshold (44.3 KeV) Pu-238 - inelastic threshold (44.3 KeV) Pu-240 - inelastic threshold (43.1 KeV) U-233 - inelastic threshold (40.6 KeV)
3.0+4	Fe - upper bound on 27.9 KeV (90b) n,n' level F - upper bound on 27.3 KeV (32b) n,n' level
2.5+4	Fe - lower bound on 27.9 KeV (90b) n,n' level F - lower bound on 27.3 KeV (32b) n,n' level Mg-25 - upper bound on 20 KeV (8.5b) n,n' level Al - lower bound on 35.04 KeV (34b) n,n' level
1.7+4	Hansen-Roach boundary Ni-58 - upper bound on 15.5 KeV (142b) n,n' level Mg-25 - lower bound on 20 KeV (8.5b) n,n' level
1.3+4	U-235 - inelastic threshold Ni-58 - lower bound on 15.5 KeV (142b) n,n' level Ni-60 - upper bound on 12.5 KeV (52b) n,n' level Cr-53 - upper bound on several levels from 3.3 to 10.5 KeV (10 to 25b)

Table A.1 (cont.)

Energy (eV)	Criterion
9.5+3	Ni-60 - lower bound on 12.5 KeV (52b) n,n' level Mn - upper bound on 8.87 KeV (140b) n,n' level
8.03+3	Pu-239 - inelastic threshold Mn - lower bound on 8.87 KeV (140b) level and upper bound on 7.17 KeV (150b) level
6+3	Na - upper bound on 2.8 KeV (380b) n,n' level Ni-62 - upper bound on 4.6 KeV (30b) n,n' level Mn - lower bound on 7.17 KeV (150b) n,n' level
3.9+3	Zr-96 - upper bound on 3.84 KeV (170b) n,n' level Mn - upper bound on 2.375 KeV (600b) n,n' level
3.74+3	Zr-96 - lower bound on 3.84 KeV (170b) n,n' level
3.0+3	Hansen-Roach boundary Zr-92 - upper bound on 2.73 KeV (160b) n,n' level Cu - upper bound on 2.55 KeV (Cu-65,22b) and 2.06 KeV (Cu-63,41b) levels Cr-53 - lower bound on several levels from 3.3 to 10.5 KeV (10 to 25b) Ni-62 - lower bound on 4.6 KeV (30b) n,n' level
2.58+3	Zr-92 - lower bound on 2.73 KeV (160b) n,n' level
2.29+3	Zr-94 - upper bound on 2.26 KeV (50b) n,n' level
2.2+3	Zr-94 - lower bound on 2.26 KeV (50b) n,n' level
1.8+3	Na - lower bound on 2.8 KeV (380b) n,n' level Cu - lower bound on 2.55 KeV (Cu-65,22b) and 2.06 KeV (Cu-63,41b) levels
1.55+3	Zr-91 - upper bound on 1.53 KeV (90b) n,n' level
1.5+3	Zr-91 - lower bound on 1.53 KeV (90b) n,n' level Mn - lower bound on 2.375 KeV (600b) n,n' level
1.15+3	Mn - upper bound on 1.098 KeV (420b) n,n' level
950	Mn - lower bound on 1.098 KeV (420b) n,n' level
683	Zr-91 - upper bound on 679 eV (75b) n,n' level

Table A.1 (cont.)

Energy (eV)	Criterion
670	Zr-91 - lower bound on 679 eV (75b) n,n' level Cu-63 - upper bound on 577 eV (23b) n,n' level
550	Hansen-Roach boundary Mn - upper bound on 337 eV (2000b) level Cu-63 - lower bound on 577 eV (23b) level
305	Zr - upper bound on 302 eV (Zr-96,55b) and 291.5 eV (Zr-91,400b) levels
285	Zr - lower bound on 302 eV (Zr-96,55b) and 291.5 eV (Zr-91,400b) levels
240	Cu-65 - upper bound on 229 eV (13b) level
210	U-238 - upper bound on 208.6 eV (900b) level Cu-65 - lower bound on 229 eV (13b) level Mn - lower bound on 337 eV (2000b) level
207.5	U-238 - lower bound on 208.6 eV (900b) level
192.5	U-238 - upper bound on 189.6 eV (2800b) level
186	U-238 - lower bound on 189.6 eV (2800b) level
122	Th-232 - upper bound on 120.75 eV (600b) level
119	Th-232 - lower bound on 120.75 eV (600b) level U-238 - upper bound on 116.9 eV (1500b) level
115	U-238 - lower bound on 116.9 eV (1500b) level Th-232 - upper bound on 112.87 eV (450b) level Sn-116 - upper bound on 111.2 eV (62b) level
108	Th-232 - lower bound on 112.87 eV (450b) level Sn-116 - lower bound on 111.2 eV (62b) level U-238 - upper bound on 102.7 eV (3700b) level Ba-135 - upper bound on 104 eV (52b) level
100	Hansen-Roach boundary U-238 - lower bound on 102.7 eV (3700b) level Ba-135 - lower bound on 104 eV (52b) level Sn-112 - upper bound on 94.8 eV (10b) level

Table A.1 (cont.)

Energy (eV)	Criterion
90	Sn-112 - lower bound on 94.8 eV (10b) level Ba-135 - upper bound on 82 eV (80b) and 88 eV (55b) levels
82	U-238 - upper bound on 81.1 eV (250b) level
80	U-238 - lower bound on 81.1 eV (250b) level
76	Pu-239 - upper bound on 74.4 eV (1300b) level
72	Pu-239 - lower bound on 74.7 eV (1300b) level Ba-135 - lower bound on 82 eV (80b) and 88 eV (55b) levels Th-232 - upper bound on 69.13 eV (1500b) level
67.5	Th-232 - lower bound on 69.13 eV (1500b) level U-238 - upper bound on 66.2 eV (3300b) level Pu-239 - upper bound on 66 eV (1000b) level
65	U-238 - lower bound on 66.2 eV (3300b) level Pu-239 - lower bound on 66 eV (1000b) level Sn-124 - upper bound on 61.95 eV (8b) level
61	Th-232 - upper bound on 59.46 eV (180b) level Sn-124 - lower bound on 61.95 eV (8b) level
59	Th-232 - lower bound on 59 eV (180b) level
53.4	Pu-239 - upper bound on 52.7 eV (1000b) level
52	Pu-239 - lower bound on 52.7 eV (1000b) level
50.6	Pu-239 - upper bound on 50.1 eV (800b) level
49.2	Pu-239 - lower bound on 50.1 eV (800b) level
48.3	Pu-239 - upper bound on 47.8 eV (200b) level Sn-118 - upper bound on 45.75 eV (12.5b) level
47	Pu-239 - lower bound on 47.8 eV (200b) level
45.2	Pu-239 - upper bound on 44.6 eV (900b) level
44	Pu-239 - lower bound on 44.6 eV (900b) level Sn-118 - lower bound on 45.75 eV (12.5b) level

Table A.1 (cont.)

Energy (eV)	Criterion
42.4	Pu-239 - upper bound on 41.7 eV (700b) level Pu-240 - upper bound on 41.6 eV (45b) level
41	Pu-239 - lower bound on 41.7 eV (700b) level Pu-240 - lower bound on 41.6 eV (45b) level Sn-117 - upper bound on 38.8 eV (20b) level
39.6	U-235 - upper bound on 39.41 eV (500b) level Pu-240 - upper bound on 38.1 eV (650b) level
39.1	U-235 - lower bound on 39.41 eV (500b) level Pu-239 - upper bound on 38.5 eV (120b) level
38	Pu-239 - lower bound on 38.5 eV (120b) level U-238 - upper bound on 36.7 eV (4800b) level
37	Sn-117 - lower bound on 38.8 eV (20b) level Pu-240 - lower bound on 38.1 eV (650b) level
35.5	U-235 - upper bound on 35.16 eV (600b) level
34.6	U-235 - lower bound on 35.16 eV (600b) level U-238 - lower bound on 36.7 eV (4800b) level
33.75	U-235 - upper bound on 33.5 eV (380b) level
33.25	U-235 - lower bound on 33.5 eV (380b) level Pu-239 - upper bound on 32.3 eV (120b) level
32.25	U-235 - upper bound on 32.05 eV (400b) level
31.75	U-235 - lower bound on 32.05 eV (400b) level
31.25	Pu-239 - lower bound on 32.3 eV (120b) level U-235 - upper bound on 30.8 eV (150b) level
30	Hansen-Roach boundary U-235 - lower bound on 30.8 eV (150b) level
27.5	Pu-239 - upper bound on 26.2 eV (300b) level
25	Pu-239 - lower bound on 26.2 eV (300b) level Th-232 - upper bound on 23.45 eV (2100b) level Ba-135 - upper bound on 24.4 eV (40b) level Pu-239 - upper bound on 22.2 eV (1000b) level

Table A.1 (cont.)

Energy (eV)	Criterion
22.5	Th-232 - lower bound on 23.45 eV (2100b) level Ba-135 - lower bound on 24.4 eV (40b) level Pu-240 - upper bound on 20.4 eV (2400b) level U-238 - upper bound on 21 eV (5500b) level Th-232 - upper bound on 21.78 eV (1500b) level
21	Pu-239 - lower bound on 22.2 eV (1000b) level Th-232 - lower bound on 21.78 eV (1500b) level
20	U-238 - lower bound on 21 eV (5500b) level U-235 - upper bound on 19.3 eV (1000b) level
19	U-235 - lower bound on 19.3 eV (1000b) level Pu-240 - lower bound on 20.4 eV (2400b) level
18.5	Pu-239 - upper bound on 17.7 eV (1100b) level Pu-241 - upper bound on 17.83 eV (1500b) level Gd-157 - upper bound on 17.1 eV (990b) level Ag-107 - upper bound on 16.3 eV (600b) level
17	Pu-239 - lower bound on 17.7 eV (1100b) level Pu-241 - lower bound on 17.83 eV (1500b) level
16	Gd-157 - lower bound on 17.1 eV (990b) level Pu-239 - upper bound on levels at 14.3 and 14.68 eV (1700b)
15.1	Pu-241 - upper bound on 14.75 eV (2500b) level
14.4	Pu-241 - lower bound on 14.75 eV (2500b) level
13.75	Pu-241 - upper bound on 13.4 eV (1800b) level Ag-107 - lower bound on 16.3 eV (600b) level Pu-239 - lower bound on levels at 14.3 and 14.68 eV (1700b) U-233 - upper bound on 12.9 eV (500b) level
12.9	Pu-241 - lower bound on 13.4 eV (500b) level U-235 - upper bound on 12.39 eV (900b) level Pu-239 - upper bound on 11.9 eV (1400b) level
11.9	U-233 - lower bound on 12.9 eV (500b) level U-235 - lower bound on 12.39 eV (900b) level U-235 - upper bound on 11.67 eV (550b) level

Table A.1 (cont.)

Energy (eV)	Criterion
11.5	Pu-239 - lower bound on 11.9 eV (1400b) level U-235 - lower bound on 11.67 eV (550b) level U-233 - upper bound on 10.45 eV (620b) level Pu-239 - upper bound on 10.95 eV (1600b) level
10	Hansen-Roach boundary U-233 - lower bound on 10.45 eV (620b) level Pu-239 - lower bound on 10.95 eV (1600b) level Hf - upper bound on 5 levels with peak at 7.78 eV (Hf-178,10,000b) In-115 - upper bound on 9.12 eV (1000b) level
9.1	U-235 - upper bound on 8.79 eV (1000b) level Ag-109 - upper bound on 5.19 eV (12,000) level Pu-241 - upper bound on 8.6 eV (1800b) level
8.1	U-235 - lower bound on 8.79 eV (1000b) level Pu-241 - lower bound on 8.6 eV (1800b) level Pu-239 - upper bound on 7.85 eV (1800b) level U-238 - upper bound on 6.67 eV (8000b) level Gd-155 - upper bound on 7.74 eV (160b) level In-115 - lower bound on 9.12 eV (1000b) level
7.15	Pu-239 - lower bound on 7.85 eV (1800b) level Gd-115 - lower bound on 7.74 eV (160b) level U-235 - upper bound on 7.08 eV (210b) level Pu-241 - upper bound on 6.93 eV (1000b) level
7	U-235 - lower bound on 7.08 eV (210b) level U-233 - upper bound on 6.82 eV (800b) level Gd-155 - upper bound on 6.302 eV (510b) level U-236 - upper bound on 5.49 eV (48000b) level
6.75	Pu-241 - lower bound on 6.93 eV (1000b) level
6.5	U-233 - lower bound on 6.82 eV (800b) level U-235 - upper bound on 6.39 eV (600b) level
6.25	U-235 - lower bound on 6.39 eV (600b) level
6	U-238 - lower bound on 6.67 eV (8000b) level Gd-155 - lower bound on 6.302 (510b) level
5.4	U-234 - upper bound on 5.19 eV (59,000b) level

Table A.1 (cont.)

Energy (eV)	Criterion
5	Hf - lower bound on 5 levels with peak at 7.78 eV (Hf-178, 10,000b) U-235 - upper bound on 4.845 eV (210b) level
4.75	U-235 - lower bound on 4.845 eV (210b) level Pu-241 - upper bound on 4.3 eV (2200b) level (couplet) In-115 - upper bound on 3.86 eV (850b) level
4	Pu-241 - lower bound on 4.3 eV (2200b) level (couplet)
3.73	U-235 - upper bound on 3.61 eV (170b) level U-233 - upper bound on 3.66 eV (280b) level U-236 - lower bound on 5.49 eV (48,000b) level
3.5	U-235 - lower bound on 3.61 eV (170b) level U-233 - lower bound on 3.66 eV (280b) level
3.15	In-115 - lower bound on 3.86 eV (850b) level U-235 - upper bound on 3.1 eV (90b) level
3.05	U-235 - lower bound on 3.1 eV (90b) level Ag-109 - lower bound on 5.19 eV (12,000b) level
3.00	Cutoff between ENDF/B hydrogen data for fast and thermal energy ranges.

[a] Read 20×10^6.

APPENDIX B

AMPX Master Library Format

N. M. Greene

An AMPX master library is not structured for direct use in a multigroup particle transport calculation. The intent is to provide a means to present a library that has the potential of being truly problem independent which can be tailored at run-time for a particular problem. The library carries data at a sufficient level of detail to allow satisfying many of the less common, but very powerful analyses such as cross-section sensitivity studies and coupled neutron-gamma transport calculations. The library can contain appropriate data to allow resonance self-shielding to be performed using the Nordheim method, the Bondarenko method or an integral transport calculation with many spatial zones. Temperature dependence of data is allowed. Any number of scattering processes can be included to any degree of anisotropic representation.

The AMPX master format has been designed to allow a generality paralleling that of the ENDF/B point libraries. For example:

1. The formats can accommodate neutron libraries, gamma libraries or coupled neutron-gamma libraries.

2. An arbitrary number of reaction cross sections can be included with ENDF/B identifiers used for processes, where possible. (See Appendix C.)

3. An arbitrary order of anisotropy can be presented which can vary from nuclide to nuclide or even from process to process.

4. Temperature dependence is allowed.

5. Resonance parameters may be included for use in Nordheim resolved resonance calculations and/or in an unresolved resonance calculation.

6. The library can contain Bondarenko data for resonance self-shielding.

7. The library can include scattering matrix data for an arbitrary number of processes.

In the case of the resonance data, partial energy range data can be specified. For example, in CSRL-V the Bondarenko data are only for the unresolved region which will vary from nuclide to nuclide.

Potentially, the most space-consuming data on a cross-section library are the transfer matrix data. AMPX uses so-called "magic-word" arrays for these data which help to eliminate zero and/or impossible data elements. This is especially important for the master library where the library may contain data for ~50 separate processes represented to an arbitrary level of anisotropy.

The master format is written using a combination of seven kinds of information, each of which has one or more record types associated with it:

1. Header information -- written on the front of the library to specify the number of neutron and/or gamma groups, the number of nuclides, etc., contained in the library. (Record Type 1)

2. Energy structure information -- contains the group boundaries. (Record Type 2)

3. Nuclide directory information -- fifty words which give a title for the nuclide along with other parameters which specify the kinds of information included for the nuclide, such as number of records in the library for the nuclide and how much neutron and gamma data are given. (Record Type 3)

4. Resonance parameter data -- provisions for resolved resonance parameters in the SLBW or MLBW formats. Average parameters for an unresolved calculation may also be included. (Record Type 4)

5. Bondarenko data -- four record types are used for this information:

   a. A record which gives the values of σ_0 and T at which the factors are tabulated, along with cutoff energies for the Bondarenko calculation. (Record Type 5)

   b. A directory record containing information about the specific processes for which the Bondarenko factor data applies, such as the process, the energy groups for which data are given, etc. (Record Type 6)

   c. A record containing infinite dilution values for a process. (Record Type 7)

   d. A record containing the Bondarenko factors for a process. (Record Type 8)

6. A record containing average cross sections by process. (Record Type 9)

7. Three record types are used to present transfer matrices:

   a. A directory record which specifies the processes, orders of anisotropy, lengths, units, etc. (Record Type 10)

   b. A record to specify temperatures when the matrices are temperature-dependent. (Record Type 11)

   c. A "magic-word" record to store a transfer matrix. (Record Type 12)

The structure of the various record types is now discussed.

Record Type 1 (Header Record)

The header record is the first record on the library and always contains 110 words:

1. IDTAPE - An identification number for the library.

2. NNUC - The number of sets of data on the library.

3. IGM - The number of neutron energy groups on the library.

4. IFTG - The first thermal neutron group on the library, i.e., the first group which receives an upscatter source.

5. MSN - Zero.

6. IPM - The number of gamma-ray energy groups on the library.

7. I1 - Zero.

8. I2 - (0/1 = no/yes) A trigger which specifies that this library was produced by weighting a working library in the AMPX XSDRNPM module.

9. I3 - Zero.

10. I4 - Zero.

11-110. (TITLE(I), I=1,100) - 100 words of text describing the cross-section library.

Record Type 2 (Energy Boundaries)

This record specifies the energy boundaries in eV of the neutron groups and/or gamma groups followed by the corresponding lethargy boundaries. The energy boundaries are arranged in ascending order followed by the lethargy boundaries in descending order. The "lethargy zero" is taken at 10 MeV. The structure is:

(EB(I),I=1,IGP), (UB(I),I=1,IGP)

where IGP is the number of groups plus one.

Record Type 3 (Cross-Section Set Directory Record)

Each set of data has a 50-word directory record which specifies certain parameters needed to determine dimensions required to process the data and to describe the make-up of the set of data. The following table describes these data:

Word(s)	Content
1-18	18 words of text describing the set
19	Identifier of the set
20	Number of six-parameter sets of resolved resonance data
21	Number of energies at which to evaluate unresolved values
22	Number of 1-D neutron processes (temperature independent)
23	Number of 2-D neutron processes
24	Zero
25	Number of 1-D gamma processes
26	Number of 2-D gamma processes
27	Number of 2-D neutron-to-gamma processes
28	(Max. order of scattering)*32768 + (total number of separate 2-D arrays for this set)
29	A - neutron equivalent mass number
30	ZA - 1000*Z + A
31	Zero
32	Zero
33	Zero
34	Power per fission in watt-sec/fission
35	Energy release per capture in watt-sec/capture
36	Maximum length of any 2-D record in the set
37	Number of sets of Bondarenko data
38	Number of σ_0's in Bondarenko data
39	Number of T's in Bondarenko data
40	Maximum number of groups in Bondarenko data
41	Zero
42	Zero
43	$\sigma_{p_{section}}$ - potential scattering cross
44	Zero
45	ENDF MAT for fast neutron data
46	ENDF MAT for thermal neutron data
47	ENDF MAT for gamma data
48	ENDF MAT for gamma production data
49	Nuclide symbol (text)
50	Number of records in this set

Note that the 50-word records are made up of integer, character and floating point words. Words 1 to 18 and word 49 are character data. Words 29, 30, 34, 35 and 43 are floating point. All other words are integers. For both types of libraries, many parameters may have no meaningful interpretation for a particular set of data. Zero values are used when a parameter is not applicable.

Record Type 4 (Resonance Parameters)

This record is present only when either the number of six-word resonance sets, NRES, or the number of unresolved energy points, NUNR, is non-zero. Its length is

$$9 + 6*NRES + NUNR .$$

All values are in floating point.

The first nine words contain parameters used in both the resolved and unresolved resonance calculations:

1. A, the mass ratio for the isotope or mixture of isotopes,
2. $^{\sigma}p_0$, the potential scattering cross section,
3. g, the average statistical factor in the unresolved region,
4. NRES, the number of six-parameter resonance sets,
5. S, a factor used in the Nordheim calculation to determine the range over which the calculation will be made,
6. $\langle D \rangle$, the average level energy spacing for the ℓ=0 unresolved sequence which will be calculated,
7. $\langle \Gamma_n^0 \rangle$, the average unresolved neutron width,
8. $\langle \Gamma_\gamma \rangle$, the average unresolved gamma width,
9. $\langle \Gamma_f \rangle$, the average unresolved fission width.

The next 6*NRES words consist of six-word sets of data used in the Norheim calculation.

1. Zero
2. NBLK, the number of blocks of resolved data,
3. Zero

4. Zero

5. Zero

6. Zero

Following these six words are NBLK six-word groups which are used to specify information concerning blocks of resonance data that apply to, for example, different isotopes, different energy regions, different kinds of data (s-wave or p-wave resonances), etc. These word groups are stacked as follows:

1. AWRI, the mass ratio associated with the block of data,

2. ABUN, the abundance for the block of data,

3. NRE, the number of resonances in the block,

4. ℓ, the value of spin for the resonances in the block,

5. EL, the low energy cut-off for resonances in the block,

6. EH, the upper energy cut-off for resonances in the block,

.
.
.

After these NBLK groups of six words, comes the six-word sets of resonance parameters arranged as follows:

1. E_0 , the resonance energy,

2. Γ_n , the neutron width of the resonance,

3. Γ_γ , the gamma width of the resonance,

4. Γ_f , the fission width of the resonance,

5. r , a factor used in the Nordheim treatment for determining the range of calculation

6. g , the statistical factor for the resonance

The following chart illustrates in a schematic manner the structure just described:

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	1	2	3	4	5	6
	0	NBLK	0	0	0	0
	$AWRI_1$	$ABUN_1$	NRE_1	ℓ_1	EL_1	EH_1
	$AWRI_2$	$ABUN_2$	NRE_2	ℓ_2	EL_2	EH_2
	.					
	.					
	.					
	$AWRI_{NBLK}$	$ABUN_{NBLK}$	NRE_{NBLK}	ℓ_{NBLK}	EL_{NBLK}	EH_{NBLK}
first block	E_0	Γ_n	Γ_γ	Γ_f	r	g
	.	.	.	.	.	.
	.	.	.	.	.	.
	.	.	.	.	.	.

After the resolved resonance parameters, the points at which the unresolved cross section should be evaluated are specified. There are NUNR of these points arranged low-to-high in energy:

(EUNR(I), I=1, NUNR)

Record Type 5 (First Record of Bondarenko Block)

This record is used to specify the σ_0 and temperature values at which all Bondarenko factors for the nuclide will be presented. It also specifies the upper and lower energies for which factors can apply in the case where they don't span all energy groups. The number of σ_0 values, NSIGO, is specified in the 38th word in the set directory, and the 39th word specifies the number of temperatures, NT. The record structure is:

(σ_0(I), I=1, NSIGO), (T(I), I=1, NT), ELO, EHI

The σ_0 values can either ascend or descend, while the temperatures are in Kelvin in ascending order.

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Record Type 6 (Directory for Bondarenko Data)

This record type is used to specify the processes which have Bondarenko data in the set. Its length is six times NBOND, the number of Bondarenko processes, specified in the 37th word in the set directory. The structure is:

(MT(I), I=1, NBOND),
(NF(I), I=1, NBOND),
(NL(I), I=1, NBOND),
(ORDER(I), I=1, NBOND),
(IOFF(I), I=1, NBOND),

The parameters have the following interpretation: MT is the identifier of the process; e.g., MT=2 is for elastic scattering as in ENDF/B. NF is the number of the first energy group for which parameters are given. NL is the last group for which parameters are given. ORDER is used to specify the order of the scattering matrix in the event it is to be self-shielded. IOFF is the offset from the "magic-word" in the transfer matrices; e.g., for elastic scattering, the first word after the magic-word is generally the within-group term such that IOFF=1 would specify the shielding for the within-group terms. (This parameter will be clearer in the discussion of AMPX transfer matrices given below.) NZ is presently unused and has a zero value.

Record Type 7 (Infinite Dilution Values for Bondarenko Data)

Each process which has Bondarenko data has one of these records which contains the infinite dilution values for the process. Its structure is

$(\sigma^{\infty}(I), I=NF, NL)$

where NF and NL are the first and last groups with data for the process.

Record Type 8 (Bondarenko Factors)

This record is a three-dimensional array and contains the Bondarenko factors for a process. Its structure is

(((BF(I,J,K), I=1, NSIGO), J=1, NT), K=NF, NL)

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Record Type 9 (Temperature-Independent Average Cross Sections)

This record type is used to present average cross sections (sometimes called one-dimensional cross sections) on the library.

Its structure is

$$MT_1, (\sigma_1(I), I=1, IGM)$$

$$MT_2, (\sigma_2(I), I=1, IGM)$$

$$\vdots$$

$$MT_{LAST}, (\sigma_{LAST}(I), I=1, IGM)$$

where the MT's are the process identifiers, and the cross sections, σ, are given for all groups. (Note that the MT's are given as floating point numbers.)

Record Type 10 (Scattering Matrix Directory)

An AMPX master library always includes a directory which identifies the scattering matrices that are given for a nuclide. The structure is

(MT(I), I=1, N2D),
(L(I), I=1, N2D),
(NL(I), I=1, N2D),
(NT(I), I=1, N2D)

where N2D is the number of scattering (two-dimensional) processes, MT is the process identifier, L is the maximum length of any of the scattering matrices for the process, NL is the order of Legendre fit to the scattering matrix, and NT is a parameter whose definition depends on the type of data (whether neutron, gamma production or gamma) given as follows:

a) For neutron-neutron data, NT is the number of temperatures at which scattering matrices are given.

b) For gamma production data, NT is zero if the data are in yield units and is unity if they are in cross section units.

c) For gamma-gamma data, NT is zero.

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Record Type 11 (Scattering Matrix Temperatures)

This record type specifies the temperatures (in eV) of the scattering matrices. It is only used for neutron-neutron data and is given when NT > 0 (see Record Type 10). The temperatures are in ascending order as follows:

(T(I), I=1, NT)

Record Type 12 (Scattering Matrix)

This record type is used to store scattering matrix data (sometimes called 2-D data). As will be illustrated, it has provisions for truncating zero and/or impossible elements from the array. It exists in two forms: (1) a self-defining form used for gamma production data and (2) a form that is not self-defining. The only difference is that the self-defining form specifies the length as the first word, while the other does not; i.e.,

L, (X(I), I=1, L)

or

(X(I), I=1, L) .

The structure of the X-array is as follows:

Magic word for a group,
Terms for scattering to the group,
Magic word for the next group,
Terms for scattering to this group,
Etc., etc.

In some cases, a negative or zero magic-word is used to specify the end of data in the record.

A "magic-word" is used to define:

a. The sink group number, III,

b. The first group number, JJJ, which scatters to this group,

c. The last group number, KKK, which scatters to this group.

The magic-word is then defined as

MW = 1000000*JJJ + 1000*KKK + III

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such that it is composed of three 3-digit integers:

MW : JJJKKKIII

The scattering terms below a "magic-word" are in reverse ordering (following typical practice for transport theory programs); i.e., the scattering term for scattering from the last group is first, etc.:

MW for group III

σ(KKK→III)

σ(KKK-1→III)

.
.
.

σ(JJJ→III)

The scattering matrix record will contain one P_ℓ matrix for a process.

Consider an elastic scattering matrix for hydrogen which will be a full triangular matrix and assume three energy groups. The scattering matrix will look as follows:

1001001
σ(1→1)
1002002
σ(2→2)
σ(1→2)
1003003
σ(3→3)
σ(2→3)
σ(1→3)

Note that the record is a mixture of integer and floating point terms.

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AMPX Master Library Format

The overall structure of an AMPX master library is given below:

	Record Type
Header Record	1
Nuclide Directory (one record per nuclide)	3
Neutron Energy Boundaries	2
Gamma Energy Boundaries	2

Records for Nuclide 1
Records for Nuclide 2
Etc.

The structure of the records of a nuclide is:

	Record Type
Nuclide Directory Record	3
Bondarenko Data	
Resonance Parameter Data	4
Temperature-Independent Group Averaged Neutron Cross Sections	9
Scattering Matrix Data for Neutrons	
Group Averaged Gamma Cross Sections	9
Scattering Matrix Data for Gammas	

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The internal structure for Bondarenko data is:

	Record Type
$(\sigma_0(I), I=1, NSIGO)$, (T(J),J=1,NT), EL, EH	5
Bondarenko Data Directory (MT(I), I=1, NB), (NF(I), I=1, NB), (NL(I), I=1, NB), (ORDER(I), I=1, NB), (IOFF(I), I=1, NB), (NZ(I), I=1, NB)	6
The following records are given in pairs for all NB Bondarenko processes.	
Infinite Dilution Values $(\sigma^{\infty}(I), I=NF, NL)$	7
Bondarenko Factors (((BF(I,J,K), I=1, NSIGO), J=1, NT), K=NF, NL)	8

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The internal structure of the scattering matrix data for neutrons is:

	Record Type
Scattering Matrix Directory (MT(I), I=1, N2D), (L(I), I=1, N2D), (NL(I), I=1, N2D), (NT(I), I=1, N2D)	10
The following structure is repeated N2D times.	
Temperature Values (NT>0) (T(I), I=1, NT)	11
The following record is repeated MAX(1,NT)*(NL+1) times.	
Scattering Matrix (X(I), I=1, L)	12

The internal structure for gamma production scattering is:

Scattering Matrix Directory (MT(I), I=1, N2D), (L(I), I=1, N2D), (NL(I), I=1, N2D), (NT(I), I=1, N2D)	10
For each process, I=1, N2D, the following record type is given NL+1 times corresponding to the P_0, P , ... P_{NL} matrices.	
Self-Defining Scattering Matrix Length LENGTH,(X(I), I=1, LENGTH)	12

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The internal structure for gamma-gamma scattering is:

	Record Type
Scattering Matrix Directory (MT(I), I=1, N2D), (L(I), I=1, N2D), (NL(I), I=1, N2D), (NT(I), I=1, N2D)	10
For each process, I=1, N2D, the following record type is given NL+1 times corresponding to the P_0, P_1, ... P_{NL} matrices.	
Scattering Matrix (X(I), I=1, L)	12

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APPENDIX C

Definitions of Reaction Type Identifiers Used in the CSRL-V Libraries

Reaction types in ENDF data are identified by integers - MT numbers. Within the AMPX system, the ENDF MT numbers are used, where possible, to identify the appropriate cross-section data. Where AMPX processed data are available that are not defined by an ENDF MT number, the data are identified by integers outside the range of the ENDF MT numbers. The following definition of reaction types is taken from Appendix B of the ENDF manual[1] - being augmented where necessary to describe identifiers assigned to AMPX processed data, i.e., the CSRL-V master and pointwise library data.

The MT number generally refers to a specific neutron-nucleus interaction mechanism, but occasionally it indicates that a particular type of information is given. The general rules for assignment of MT numbers are as follows:

MT (range)	Description of Class of Reactions
1-100	Reaction types in which secondary particles of the same type as the incident particles are emitted
101-150	Reaction types in which no secondary particles of the same type as the incident particles are emitted
151-200	Resonance region information
201-450	Quantities derived from the basic data
451-699	Miscellaneous quantities
700-799	Excitation cross sections for reactions that emit charged particles
800-999	(not assigned)
1000-2000	AMPX special identifiers

Within AMPX, different modules can assign the same MT number to a more or less inclusive set of data pertaining to the implied reaction. Specific MT assignments are given in the following table. Situations where different AMPX modules use the same MT number to identify the more or less inclusive data are identified below.

MT	Description
1	Total cross section (redundant, equal to the sum of all partial cross sections)
2	Elastic scattering cross section
3	Nonelastic cross section (redundant, equal to the sum of all partial cross sections except elastic scattering)
4	Total inelastic cross section (redundant, equal to the sum of MT = 51, 52, 53,..., 90, 91)
5	(to be assigned)
6	(n,2n) cross section for first excited state (describes first neutron)
7	(n,2n) cross section for second excited state (describes first neutron)
8	(n,2n) cross section for third excited state (describes first neutron)
9	(n,2n) cross section for fourth excited state (describes first neutron)
10-15	(to be assigned)
16	direct (n,2n) cross section [total (n,2n) cross section is sum of MT = 6, 7, 8, 9 and 16]
17	(n,3n) cross section
18	Total fission cross section (sum of MT = 19, 20, 21, 38). For resonance nuclei the following should be noted: 1. The XLACS-2 produced MT = 18 data contain the File 3 background, the contribution from the fission resonance wings (per Nordheim treatment), and all $\ell \geq 1$ resonances. 2. When a resonance calculation is <u>not</u> triggered in the NITAWL module, the fission cross sections in NITAWL-produced libraries are the sum of the MT = 18 and MT = 1022 data on the input master library. When a resonance <u>is</u> triggered

MT	Description
	in the NITAWL module, the NITAWL-produced MT = 18 cross sections are the sum of the MT = 18 data on the input master library and the fission resonance self-shielded cross sections based on the Nordheim integral treatment.
	3. NPTXS produced MT = 18 point cross sections include the contributions from the File 3 MT = 18 data and from the processed MT = 18 resolve and unresolved data from File 2.
19	(n,f) cross section (first chance fission)
20	(n,n'f) cross section (second chance fission)
21	(n,2nf) cross sections (third chance fission)
22	(n,n'α) cross section
23	(n,n'3α) cross section
24	(n,2nα) cross section
25	(n,3nα) cross section
26	(n,2n) isomeric state cross section
27	Absorption cross section (sum of MT = 18 and 101) includes particle reactions
28	(n,n'p) cross section
29	(n,n'2α) cross section
30	(n,2n2) cross section
31	Used only in ENDF/B data as an LR flag to indicate that γ-emission is the mode of decay of the residual nucleus formed in the primary reaction[a]
32	(n,n'd) cross section
33	(n,n't) cross section

[a] The "primary" reaction could be, for example, an (n,n'), (n,p), (n,α), (n,n´p), etc., reaction.

MT	Description
34	(n,n'^{3}He)
35	(n,n'd2α) cross section
36	(n,n't2α) cross section
37	(n,4n) cross section
38	(n,3nf) cross section (fourth chance fission)
39	Used only in ENDF/B data to indicate that internal conversion is the mode of decay of the residual nucleus formed in the primary reaction[a]
40	Used only in ENDF/B data to indicate that electron-position pair formation is the mode of decay of the residual nucleus formed in the primary reaction[a]
41-45	(to be assigned)
46	cross section for describing the second neutron from (n,2n) reaction for first excited state
47	cross section for describing the second neutron from (n,2n) reaction for second excited state
48	cross section for describing the second neutron from (n,2n) reaction for third excited state
49	cross section for describing the second neutron from (n,2n) reaction for fourth excited state (Note: MT = 46, 47, 48, and 49 should not be included in the sum for the total (n,2n) cross section.)
50	(to be assigned)
51	(n,n') to the first excited state
52	(n,n') to the second excited state
.	
.	
.	

[a] The "primary" reaction could be, for example, an (n,n'), (n,p), (n,α), (n,n'p), etc., reaction.

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MT	Description
90	(n,n') to the 40th excited state
91	(n,n') to the continuum
92-100	(to be assigned)
101	neutron disappearance (sum of all cross sections in which a neutron is not in the exit channel), i.e., $MT = 101 \text{ is } \sum_{i=2}^{14} (MT=100+i)$
102	(n,γ) radiative capture cross section. For resonance nuclei, the following should be noted: 1. The XLACS-2 produced MT = 102 data contain the File 3 background, the contribution from the (n,γ) resonance wings (per Nordheim treatment), and all $\ell \geq 1$ resonances. 2. When a resonance calculation is <u>not</u> triggered in the NITAWL module, the (n,γ) cross sections in NITAWL-produced libraries - identified as MT = 102 cross sections - are the sum of the MT = 102 and MT = 1021 data on the input master library. When a resonance <u>is</u> triggered in the NITAWL module, the NITAWL produced MT = 102 cross sections are the sum of the MT = 102 data on the input master library and the (n,γ) resonance self-shielded cross sections based on the Nordheim integral treatment. 3. NPTXS produced MT = 102 point cross sections include the contribution from the File 3 MT = 102 data and from the processed MT = 102 resolved and unresolved resonance data from File 2.
103	(n,p) cross section
104	(n,d) cross section
105	(n,t) cross section

MT	Description
106	(n,^{3}He) cross section
107	(n,α) cross section
108	(n,2α) cross section
109	(n,3α) cross section
110	(to be assigned)
111	(n,2p) cross section
112	(n,pα) cross section
113	(n,t2α) cross section
114	(n,d2α) cross section
115-119	(to be assigned)
120	Target destruction = nonelastic less total (n,n'γ)
121-150	(to be assigned)
151	General designation for resonance information
152-200	(to be assigned for specific resonance information)
201-202	(to be assigned)
203	Total hydrogen production
204	Total deuterium production
205	Total tritium production
206	Total ^{3}He production
207	Total ^{4}He production
208-250	(to be assigned)
251	$\bar{\mu}_L$; the average cosine of the scattering angle (laboratory system) for elastic scattering
252	ξ, the average logarithmic energy decrement for elastic scattering

MT	Description
253	γ, the average of the square of the logarithmic energy decrement for elastic scattering, divided by twice the average logarithmic decrement for elastic scattering
254-300	(to be assigned)
301-450	Energy release rate parameters, $\overline{E^*\sigma}$, for total and partial cross sections. Subtract 300 from this number to obtain the specific reaction type identification. For example, MT = 302 = (300 + 2) denotes elastic scattering
451	Heading or title information (given only in File 1)
452	$\overline{\nu}$, average total (prompt plus delayed) number of neutrons released per fission event
453	Radioactive nuclide production
454	Fission product yield data
455	Delayed neutrons from fission
456	Prompt neutrons from fission
457	Radioactive decay data
458	Energy release in fission
459-500	(to be assigned)
501	Total photon interaction cross section
502	Photon coherent scattering
503	(to be assigned)
504	Photon incoherent scattering
505-514	(to be assigned)
515	Pair production, electron field
516	Pair production, nuclear and electron field (i.e., pair plus triplet production)
517	Pair production, nuclear field

MT	Description
518	Photofission (γ,f)
519-526	(to be assigned)
527	Sum of all gamma-ray absorption processes
528-531	(to be assigned)
532	Photoneutron (γ,n)
533	Total photonuclear
534-601	(to be assigned)
602	Photoelectric
603-699	(to be assigned)
700	(n,p_0) cross section (cross section for leaving the residual nucleus in the ground state)
701	(n,p_1) cross section for 1st excited state
702	(n,p_2) cross section for 2nd excited state
703	(n,p_3) cross section for 3rd excited state
704	(n,p_4) cross section for 4th excited state
.	
.	
.	
718	(n,p_c) cross section for continuum excited state
719	(n,p_c') cross section for continuum specifically not included in total (redundant, used for describing outgoing proton)
720	(n,d_0) cross section for ground state
721	(n,d_1) cross section for 1st excited state
722	(n,d_2) cross section for 2nd excited state
.	
.	
.	
738	(n,d_c) cross section for continuum excited state

MT	Description
739	(n,dc') cross section for continuum specifically not included in σ total (redundant, used for describing outgoing deuteron)
740	(n,t_0) cross section for ground state
741	(n,t_1) cross section for 1st excited state
742	(n,t_2) cross section for 2nd excited state
.	
.	
.	
750	(n,t_c) cross section for continuum excited state
759	(n,tc) cross section for continuum specifically not included in σ total (redundant, used for describing outgoing triton)
760	$(n, {}^3He_0)$ cross section for ground state
761	$(n, {}^3He_1)$ cross section for 1st excited state
.	
.	
.	
778	$(n, {}^3He_c)$ cross section for continuum
779	$(n, {}^3He_c)$ cross section for continuum specifically not included in σ total (redundant, used for describing outgoing ^3He)
780	(n,α_0) cross section for ground state
781	(n,α_1) cross section for 1st excited state
.	
.	
.	
798	(n,α_c) cross section for continuum
799	(n,α_c') cross section for continuum specifically not included in σ_T (redundant, used to describe outgoing α)

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MT	Description
800-999	(to be assigned)
1000[a]	XSDRNPM-produced transport cross section based on the outscatter approximation, i.e., $\sigma_{tr} \approx \sigma_a + (1 - \overline{\mu})\sigma_s$ (Note: σ_a is MT 27; σ_s is MT 2.)
1001[a]	XSDRNNPM-produced transport cross section based on the inscatter approximation, i.e., $\sigma_{tr} \equiv \sigma_t - \frac{\int_0^\infty \sigma_1(E' \quad E) j(E') dE'}{3j(E)}$
1007	Thermal scattering matrix where upscatter is present - can be coherent and incoherent data
1018	Chi (χ) distribution of neutrons from the fission reaction. Chi is represented in ENDF File 5 data as a function of neutron energy. XLACS-2 calculates energy dependent χ's by group and weights the χ's over the fission rate ($\nu\Sigma_f\phi$) to produce a single vector.
1021	These data, which are generated by XLACS-2 only when processing resonance nuclides, are the "bodies" of the $\ell = 0$ resonances for the (n,γ) reaction, weighted over the specified weighting option. (The "body" of a resonance is the energy range over which the Nordheim integral treatment is used in the NITAWL module to calculate resonance self-shielded data.) When a resonance calculation is <u>not</u> specified for a resonance nuclide in NITAWL, the MT = 1021 and MT = 102 data on the master library are summed and identified as the (n,γ) cross sections - MT 102 data - in any cross-section library produced by NITAWL. (Note that when a 1/E weighting function is used in the resonance range in XLACS-2, the

[a] Transport cross sections are current weighted in XSDRNPM. All other cross sections are flux weighted.

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MT	Description
	sum of the MT = 1021 and MT = 102 data is, by definition, the infinite dilution cross sections.) When a resonance calculation is triggered in NITAWL, the MT = 1021 data do not appear in any NITAWL-produced library.
1022	Fission "body" of the ℓ = 0 resonance data which is analogous to the MT = 1021 data.
1023	Elastic scattering "body" of the ℓ = 0 resonance data which is analogous to the MT = 1021 data.
1099	Group integral of the weight function triggered by IW (1$$ array) in XLACS-2.
1452	Product of nu times the fission cross section.
1500-1501	Same as 1000-1001 except for gamma-ray cross sections.
1527	Gamma-ray energy absorption coefficients. These data are also called kerma factors.

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16. ABSTRACT (200 words or less)

A P_3 227-neutron-group cross-section library has been processed for the subsequent generation of problem-dependent fine- or broad-group cross sections for a broad range of applications, including shipping cask calculations, general criticality safety analyses, and reactor core and shielding analyses. The energy group structure covers the range 10^{-5} eV - 20 MeV, including 79 thermal groups below 3 eV. The 129-material library includes processed data for all materials in the ENDF/B-V General Purpose File, several data sets prepared from LENDL data, hydrogen with water- and polyethelene-bound thermal kernels, deuterium with D_2O-bound thermal kernels, carbon with a graphite thermal kernel, a special 1/V data set, and a dose factor data set. The library, which is in AMPX master format, is designated CSRL-V (Criticality Safety Reference Library based on ENDF/B-V data).

Also included in CSRL-V is a pointwise total, fission, elastic scattering, and (n,γ) cross-section library containing data sets for all ENDF/B-V resonance materials. Data in the pointwise library were processed with the infinite dilute approximation at a temperature of 296 K.

17. KEY WORDS AND DOCUMENT ANALYSIS
17a. DESCRIPTORS
Criticality
Shielding
Cross-sections
Reactor Safety
ENDF/B-V
SCALE

17b. IDENTIFIERS OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
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CSRL-V: PROCESSED ENDF/B-V 227-NEUTRON-GROUP AND POINTWISE CROSS-SECTION LIBRARIES FOR CRITICALITY SAFETY, REACTOR, AND SHIELDING STUDIES

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